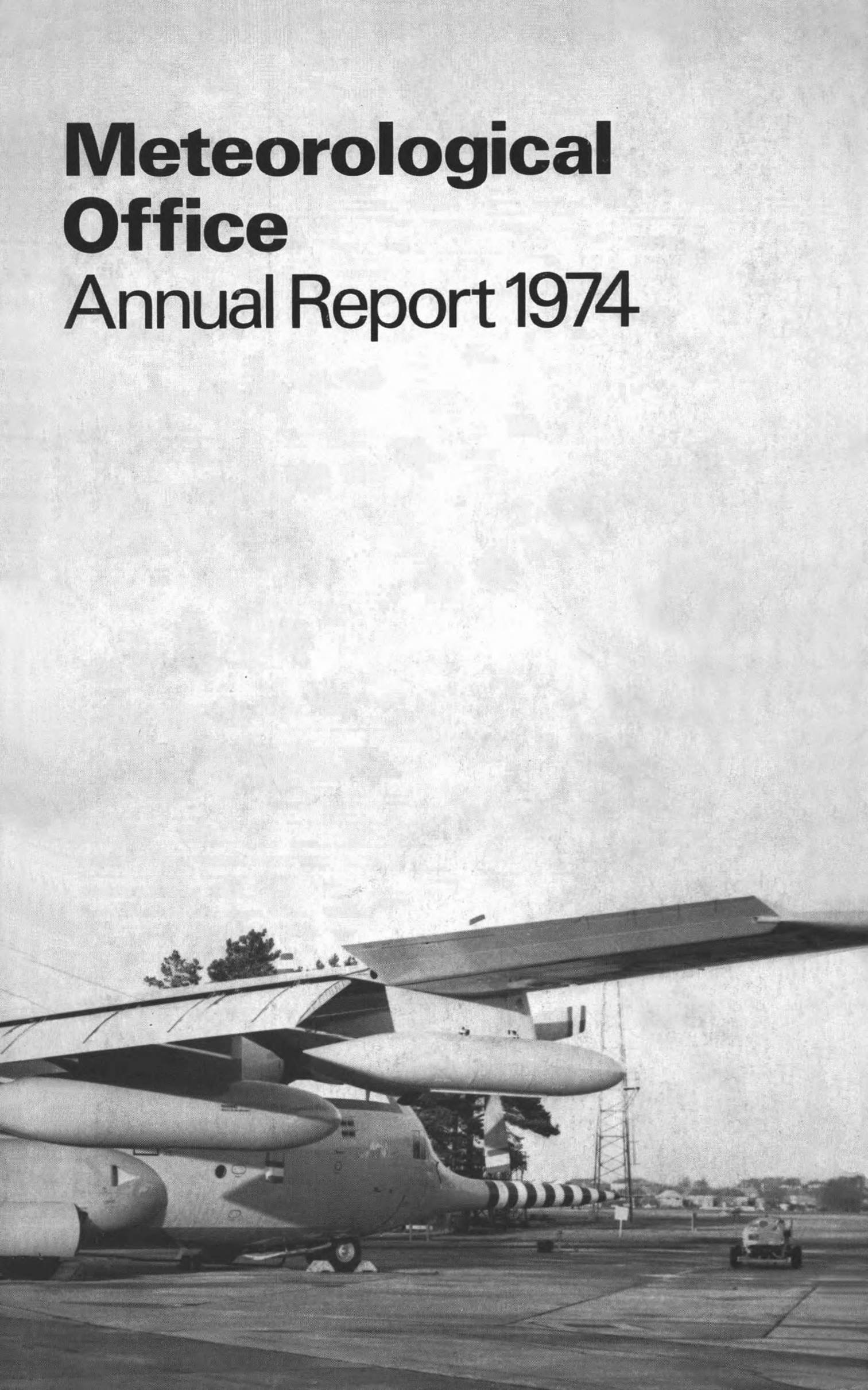
Meteorological Office

Annual Report 1974



Met O 881

ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE
1974

Presented by the Director-General
to the
Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE
1975

U.D.C.
551.5(058)

© *Crown copyright* 1975

ISBN 0 11 400288 6

Cover photograph: *The Hercules aircraft of the Meteorological Research Flight.*

FOREWORD BY THE DIRECTOR-GENERAL

In a year in which the weather showed marked deviations from the normal pattern, the Meteorological Office was hard pressed to cope with all the demands for its services. Following a marked increase in 1973, the number of inquiries from industry and the general public jumped to a new record total of 1·9 million. The poor weather in the main harvesting and holiday season produced a peak of 215 000 inquiries in August. In addition, 1·7 million forecasts were issued for aviation and 16·3 million calls (a 5 per cent increase on 1973) were made on the Automatic Telephone Weather Service.

In the industrial sector there has been a greatly increased demand for our special services for offshore oil-drilling operations. Detailed forecasts for up to 72 hours ahead are supplied to exploration rigs, production platforms, survey and pipe-laying vessels in 45 different locations. The number of climatological inquiries increased by 11 per cent to 19·5 thousand. These covered a wide variety of interests; for example, the planning of a new motorway over the Pennines, the Flixborough disaster, the destruction of power lines in Argentina and the design of a sewerage scheme in Iraq.

The numerical models that form the basis of the daily weather forecast are undergoing continuous development and a number of improvements have been incorporated during the year. However, the accuracy of the predictions depends not only on the quality of the model and the available computing power but also on an adequate supply of observations. We therefore much regret the withdrawal of the United States weather ships from the western Atlantic and are relieved that agreement has been reached on retaining four eastern Atlantic stations until at least 1981. From mid 1975, however, the Meteorological Office will man only one station instead of two, and the U.S.S.R. will join the scheme for the first time. The Office will need to refurbish the best two of its four old vessels to meet this commitment. In order to help compensate for the loss of the U.S. weather ships and the reduction in surface observations received from merchant ships, additional effort is being devoted to the incorporation of observations from satellites and aircraft into the computer analysis. A comprehensive three-dimensional scheme for the objective analysis of observations, including vertical temperature profiles derived from satellite-borne infra-red radiometers, is now fully operational.

The IBM 360/195 computer system became saturated during the year and time for research had to be severely rationed. The situation will soon be relieved, however, by the addition of an IBM 370/158 computer as a front-end processer which will effectively double the power of the whole system and act as a back-up should the main computer break down. Despite delays in the delivery of equipment, good progress was made in the second phase of automating the telecommunication system which allows automatic selection, editing and compilation of data, including error detection and control, and provides high-speed connections to several other European centres. A high-speed electronic interface allowing direct transfer of data between the small computers controlling the telecommunication system and the large computer has been commissioned.

Turning now to research, the Meteorological Office made a substantial contribution to the Atlantic Tropical Experiment (GATE) which took place

from June to September 1974 as part of the Global Atmospheric Research Programme (see Plates II and III). In what was probably the largest and most complex international scientific experiment ever undertaken, 10 nations contributed 39 specially equipped ships, 13 large research aircraft, several meteorological satellites and some 5000 personnel to an intensive three-month study of weather systems in the tropical eastern Atlantic Ocean. Four British ships participated—the survey ship HMS *Hecla*, RRS *Discovery* and two ships chartered by the Meteorological Office. They were equipped to make comprehensive surface and upper-air observations, the *Hecla* and *Discovery* also making a major contribution to the oceanographic programme. The Meteorological Office Hercules flying laboratory, operating from Dakar, was probably the best-equipped aircraft in the experiment. Both the aircraft and its equipment performed extremely well in their first major exercise. It fulfilled every one of its 40 missions, totalling 336 hours, and collected some 1000 million items of meteorological data that will take 1½–2 years to process and analyse. During the experiment, the Meteorological Office tested a numerical model of the tropical atmosphere and produced real-time analyses and forecasts of the weather in the GATE area.

As Chairman of the international Board of Management, I am happy to report that the experiment went remarkably smoothly and, although one cannot be certain until the vast mass of data is analysed, there is good reason to believe that the main scientific objectives will be achieved and that our knowledge and understanding of tropical weather systems will be greatly enhanced thereby. The success of the experiment owes much to the three years of careful and detailed planning carried out mainly in Bracknell by the International Scientific and Management Group under the direction of Dr J. Kuettner. There remains the most important task of processing and analysing the enormous quantities of data and presenting the results in a form that can be used by the international scientific community. Much of the work will be done at national level but five sub-programme data centres have been established in different countries to co-ordinate the work and produce consistent and validated data sets. The Meteorological Office has undertaken responsibility for all the synoptic-scale meteorological data.

A good deal of effort has been devoted to meteorological satellites, both in preparation for the launch of the European geostationary satellite early in 1977 and in building stratospheric temperature-sounding units for the next generation of U.S. polar-orbiting satellites. A new group has been formed to develop improved methods of deducing tropospheric temperature and humidity profiles, cloud height and cover, from satellite data.

Research in dynamical meteorology continues to be concentrated on the development of numerical models to predict and simulate weather and climate. A number of improvements have been made during the year in the 11-level global model, notably in better representation of the processes in the lowest atmospheric layers and in treating the effects of clouds on radiative transfer. The stability of the model has been demonstrated by running it for more than 100 atmospheric days and its realism tested by making forecasts for 6–10 days ahead, with encouraging success. Another version of the model, extended to 13 levels, has been developed to simulate the stratospheric circulation up to heights of 45 km. The model has successfully simulated 'sudden warmings' in which the temperature at 40 km increases by as much as 60 degC and the winds reverse from very strong westerly to easterly within a few days. A number of experiments have been carried out to study the effects in both the stratosphere

and troposphere of varying the amounts of ozone, water vapour and aerosol in the stratosphere. The results so far show that large changes of this kind in the stratosphere cause only small changes in the lower atmosphere that are difficult to detect above the natural fluctuations. Such calculations are thus in accord with observations that have followed large volcanic eruptions, and promise to be the best method of checking on the fashionable if ill-founded predictions of climatic catastrophe. Good progress has also been made in incorporating into this model the photochemistry of ozone and other minor constituents with the object of studying the combined effects of air motions and photochemical processes on the concentrations of stratospheric ozone, and of estimating the reduction of ozone that might result from the injection of nitrogen oxides by supersonic transport aircraft. Preliminary indications are that any changes produced by the numbers of aircraft expected to fly during the next decade are likely to be very small and undetectable.

It has been a particularly busy year for the Meteorological Office College where a record number of students have attended courses, 53 of them from countries overseas. For the first time the residential accommodation has proved inadequate and several students have had to live in lodgings.

The year 1974 was another outstandingly successful one for the recruitment of graduates, over 50, including 15 Ph.D.s, being appointed. At the beginning of the year there was a shortage of junior grades but a determined recruiting and training programme brought the Office up to full strength in almost all Branches by the autumn.

On a personal note, we were all delighted that Mr J. S. Sawyer's outstanding contributions to dynamical meteorology were recognized by the World Meteorological Organization awarding him the IMO Gold Medal and Prize, its highest honour. Of the 19 recipients of this Prize, six have served in the Meteorological Office.

B. J. MASON

January 1975
Meteorological Office
Bracknell, Berks.

CONTENTS

	Page
FOREWORD BY THE DIRECTOR-GENERAL	iii
FUNCTIONS OF THE METEOROLOGICAL OFFICE	viii
COMMITTEES	ix
PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE	xi
METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION	xiv
DIRECTORATE OF SERVICES	
Special topic—Instrumentation for operational meteorology	1
Forecasting services	9
Climatological services	21
Hydrometeorology	24
Services for agriculture	28
Observational requirements and practices	30
Operational instrumentation	37
Computing and data processing	43
Systems development	47
Meteorological telecommunications	51
International and planning	56
Statistics	60
DIRECTORATE OF RESEARCH	
Special topic—Studies of the dynamics and composition of the stratosphere	68
Physical research	78
Dynamical and synoptic research	89
General activities of the Research Directorate	100
Library, Publications, Archives and Cartographic Section	100
Professional Training	101
Statistics	105
INTERNATIONAL CO-OPERATION	107
STAFF	
General	116
Honours and distinctions	117

APPENDICES

I. BOOKS OR PAPERS BY MEMBERS OF THE STAFF	118
II. A SELECTION OF THE LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF	124
III. PUBLICATIONS	130

FUNCTIONS OF THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

The general functions of the Meteorological Office are:

(a) The provision of meteorological services for the Army, Royal Air Force, Civil Aviation, the Merchant Navy and Fishing Fleets.

(b) Liaison with the Director of Naval Oceanography and Meteorology, and provision of basic meteorological information for use by the Royal Navy.

(c) The provision of meteorological services to other government departments, public corporations, local authorities, the Press, television, radio, industry and the general public.

(d) The organization of meteorological observations, including observations of radiation and atmospheric electricity, in the United Kingdom and at certain stations overseas.

(e) The collection, distribution and publication of meteorological information from all parts of the world.

(f) The maintenance of the observatories at Kew and Lerwick.

(g) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization, and acts in concert with the other Directors of Meteorological Services in western Europe in the co-ordination of their programmes.

Except for the common services provided by other government departments as part of their normal functions (e.g. accommodation by the Property Services Agency of the Department of the Environment, and stationery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross expenditure of the Meteorological Office, including that on the common services, was approximately £18·4 million in 1974. Of the amount chargeable to Defence Votes, about £9·8 million represents expenditure associated with staff and £8·2 million expenditure on stores, communications and miscellaneous services. Some £4·1 million was recovered from other government departments and outside bodies in respect of services rendered, sales of meteorological equipment etc.

COMMITTEES

METEOROLOGICAL COMMITTEE

Terms of reference:

(a) To keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy.

(b) To keep under review the general scale of effort and expenditure devoted to the meteorological services.

(c) To ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

Membership at 31 December 1974:

Chairman: The Earl of Halsbury, F.R.S.

Members: Professor R. L. F. Boyd, C.B.E., F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)
Professor A. H. Bunting, C.M.G.
Sir Frederic Harmer, C.M.G.
Sir Arthur Hetherington, D.S.C.

Secretary: Mr H. E. Davies (Secretary, Meteorological Office)

The Committee met four times in 1974.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

(a) To review the development of meteorological science and its application to Scotland.

(b) To submit to the Meteorological Committee any proposal in connection therewith.

Membership at 31 December 1974:

Chairman: Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)

Members: Dr H. E. Butler, F.R.S.E. (Royal Society of Edinburgh)
Sir Samuel C. Curran, F.R.S. (Royal Society)
Professor S. Desmond Smith, F.I.P., F.R.S.E., (Heriot-Watt University)
Mr G. S. Lawrie (Department of Agriculture and Fisheries for Scotland)
Professor H. Meidner (University of Stirling)
Professor P. A. Sheppard, C.B.E., F.R.S. (Royal Meteorological Society)
Mr J. W. Shiell (Scottish Development Department)
Dr J. H. Steele (Department of Agriculture and Fisheries for Scotland)
Professor D. W. N. Stibbs, F.R.S.E. (University of St Andrews)
Professor P. A. Sweet (University of Glasgow)

Secretary: Mr D. R. Grant (Meteorological Office)

The Committee met once in 1974.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Parliamentary Under-Secretary of State for Defence for the Royal Air Force on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint subcommittees, one of which shall be responsible for advising on the use of money allocated annually from Defence Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its subcommittees.

Membership at 31 December 1974:

Chairman: Professor R. L. F. Boyd, C.B.E., F.R.S.

Members:
- Mr J. K. Bannon, I.S.O. (Director of Services, Meteorological Office)
- Instructor Captain J. A. Bell, R. N. (Director of Naval Oceanography and Meteorology)
- Professor H. Charnock
- Professor D. R. Davies
- Dr E. R. R. Holmberg (Army Department)
- Dr J. T. Houghton, F.R.S.
- Dr K. H. Stewart (Deputy Director, Physical Research, Meteorological Office)
- Mr F. H. Bushby (Deputy Director, Dynamical Research, Meteorological Office)
- Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)
- Mr F. O'Hara (Procurement Executive, Ministry of Defence)
- Professor R. P. Pearce, F.R.S.E.
- Mr J. S. Sawyer, F.R.S. (Director of Research, Meteorological Office)
- Dr P. F. G. Twinn (Natural Environment Research Council)
- Professor P. A. Sheppard, C.B.E., F.R.S.
- Professor R. C. Sutcliffe, C.B., O.B.E., F.R.S.
- Wing Commander N. E. Wilkins, D.F.C. (Air Force Department)

Secretary: Mr F. E. Dinsdale (Meteorological Office)

The Committee met twice in 1974 and its subcommittees seven times.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

B. J. Mason, C.B., D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

J. S. Sawyer, M.A., F.R.S.

DIRECTORATE OF SERVICES

DIRECTOR — J. K. Bannon, I.S.O., B.A.

INTERNATIONAL AND PLANNING

Assistant Director	D. G. Harley, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR — M. H. Freeman, O.B.E., M.Sc.

CENTRAL FORECASTING

Assistant Director	G. R. R. Benwell, M.A.
Chief Forecasting Adviser	T. H. Kirk, B.Sc.
Special Post	R. Dixon, B.Sc.

DEFENCE SERVICES

Assistant Director	E. Evans, M.Sc.
H.Q., Strike Command	R. A. Buchanan, M.A.

PUBLIC SERVICES

Assistant Director	D. H. Johnson, M.Sc., D.I.C., A.R.C.S.
London/Heathrow Airport	R. E. Farms, B.Sc.

COMMUNICATIONS AND COMPUTING

DEPUTY DIRECTOR — G. A. Corby, B.Sc.

TELECOMMUNICATIONS

Assistant Director	E. J. Bell, C.Eng., F.I.E.E.

DATA PROCESSING

Assistant Director	G. A. Howkins, M.B.E., B.Sc.

SYSTEMS DEVELOPMENT

Assistant Director	E. J. Sumner, B.A.

OBSERVATIONAL SERVICES

DEPUTY DIRECTOR — N. Bradbury, B.Sc.

Observational Requirements and Practices
- Assistant Director — L. S. Clarkson, M.Sc.
- Marine Superintendent — G. A. White, Captain, Extra Master

Climatological Services
- Assistant Director — P. F. Illsley, B.Sc.

Agriculture and Hydrometeorology
- Assistant Director — R. Murray, M.A.
- Special Post — L. P. Smith, B.A.

Operational Instrumentation
- Assistant Director — M. J. Blackwell, M.A.

DIRECTORATE OF RESEARCH

DIRECTOR — J. S. Sawyer, M.A., F.R.S.

PHYSICAL RESEARCH

DEPUTY DIRECTOR — K. H. Stewart, PhD.

Boundary Layer Research
- Assistant Director — F. B. Smith, Ph.D.

GEOPHYSICAL FLUID DYNAMICS LABORATORY — R. Hide, Sc.D., F.R.S.

Meteorological Research Flight — D. G. James, Ph.D.

Cloud Physics
- Assistant Director — P. Goldsmith, M.A.
- Special Post — K. A. Browning, Ph.D., D.I.C.*

High Atmosphere
- Assistant Director — N. E. Rider, D.Sc.

---

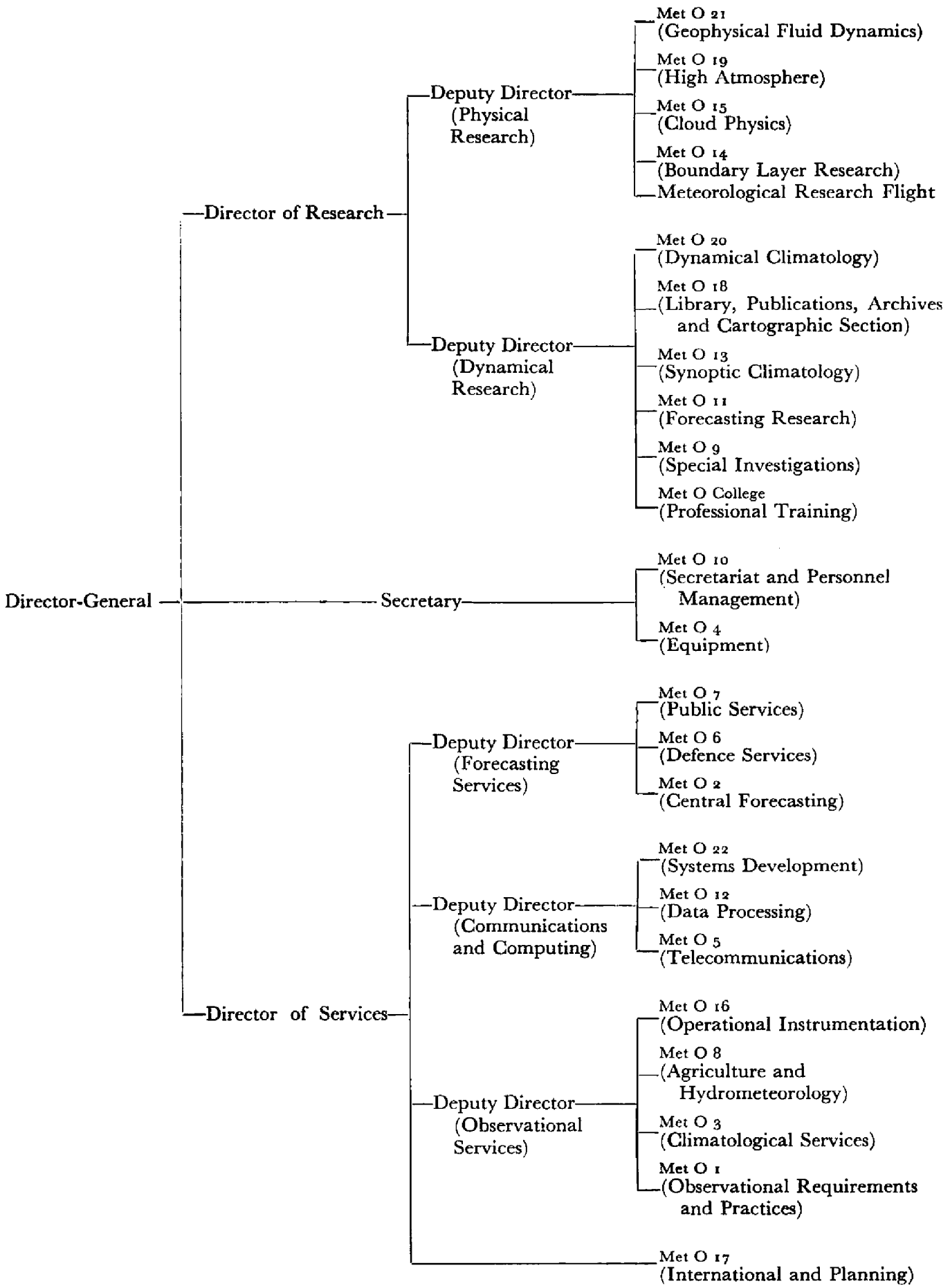
* Absent on special leave.

DEPUTY DIRECTOR	F. H. Bushby, B.Sc., A.R.C.S.
SPECIAL POST	R. J. Murgatroyd, O.B.E., Ph.D., C.Eng., M.I.E.E.
SPECIAL INVESTIGATIONS	
Assistant Director	J. Briggs, B.A.
FORECASTING RESEARCH	
Assistant Director	P. Graystone, B.A.
SYNOPTIC CLIMATOLOGY	
Assistant Director	R. A. S. Ratcliffe, M.A.
Special Post	J. M. Craddock, M.A.
PROFESSIONAL TRAINING	
Assistant Director and Principal, Meteorological Office College	D. E. Jones, M.Sc., D.I.C., A.R.C.S.
DYNAMICAL CLIMATOLOGY	
Assistant Director	A. Gilchrist, M.A.

SECRETARY, METEOROLOGICAL OFFICE	H. E. Davies, M.A.
PERSONNEL MANAGEMENT	W. D. S. McCaffery, B.Sc.

METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

(at 31 December 1974)


Director-General
Director of Research
Deputy Director (Physical Research)
Met O 21 (Geophysical Fluid Dynamics)
Met O 19 (High Atmosphere)
Met O 15 (Cloud Physics)
Met O 14 (Boundary Layer Research)
Meteorological Research Flight
Deputy Director (Dynamical Research)
Met O 20 (Dynamical Climatology)
Met O 18 (Library, Publications, Archives and Cartographic Section)
Met O 13 (Synoptic Climatology)
Met O 11 (Forecasting Research)
Met O 9 (Special Investigations)
Met O College (Professional Training)
Secretary
Met O 10 (Secretariat and Personnel Management)
Met O 4 (Equipment)
Director of Services
Deputy Director (Forecasting Services)
Met O 7 (Public Services)
Met O 6 (Defence Services)
Met O 2 (Central Forecasting)
Deputy Director (Communications and Computing)
Met O 22 (Systems Development)
Met O 12 (Data Processing)
Met O 5 (Telecommunications)
Deputy Director (Observational Services)
Met O 16 (Operational Instrumentation)
Met O 8 (Agriculture and Hydrometeorology)
Met O 3 (Climatological Services)
Met O 1 (Observational Requirements and Practices)
Met O 17 (International and Planning)

DIRECTORATE OF SERVICES

Special Topic—Instrumentation for Operational Meteorology

Introduction

The Operational Instrumentation Branch is responsible for designing, developing or adapting instruments and systems to meet the operational needs of the forecasting, climatological and hydrometeorological branches. No meteorological service can operate without observations and these for the most part cannot be obtained without instruments. Routine observations must conform to closely prescribed standards of accuracy, but must be obtained economically and in a manner convenient to the user.

Since 1971, most of the Branch has been accommodated at Beaufort Park, about 4 miles ($\approx$ 6 km) to the south-west of Bracknell. The Branch headquarters building (shown at A in Figure 1) houses custom-built laboratories for surface and upper-air instrument development and for electronics, administrative offices, engineering drawing office, electronic, mechanical and installation workshops, and photographic facilities. The new operations building (B in Figure 1) is equipped with a wind-finding radar and facilities to enable radiosondes, balloons and radar targets to be tested. The new rotating balloon shed (C) enables balloons to be launched in almost all weather conditions. The field station building (D) houses the School of Technical Training and the local servicing centre. Between this and the Branch headquarters building is a well-exposed trials ground where many new instruments now undergo field testing.

The general instrument testing, calibration and standards laboratory is at Western Road, Bracknell, some 3 miles ($\approx$ 5 km) to the north; the radiosonde calibration plant and wind tunnel are at Eastern Road, some four miles ($\approx$ 6 km) to the north-east. At the main Headquarters site at London Road, there is a specialized servicing centre which provides technical support to the Meteorological Telecommunications Centre, and a second workshop which carries out small mechanical jobs, particularly for the physical-research branches.

In reviewing the present position in instrumentation for operational meteorology, it is interesting to recall the summary given in the *Annual Report* 1966 Special Topic which dealt with 'Instrument development in recent years':

'The emphasis within the whole field of meteorological instrument development at the present time can be summarized as the employment of modern materials and electronic techniques to provide greater accuracy of measurement together with enhanced convenience to the operator. Coupled with this is the desire to reduce, where practicable, the variety of instruments with otherwise similar functions, and to standardize and make automatic the methods of recording and processing meteorological data.'

Progress and developments since 1966 have been broadly in accord with these views but, before describing the current situation, a brief account will be given of the present structure of the Branch and how the various technical services are used in support of instrumental projects. The main part of the

article reviews the new instruments and systems coming into service and the contribution they are making to the observational network. Finally, a general look ahead is made into the broad aspects of future developments.

Organization

The Branch has two development groups: the first concerned with upper-air instrumentation and largely occupied at present with the introduction into service of the complex Mk 3 radiosonde system. Because the latter is a computer-based system, the group provides general 'software' support to other projects concerned with instruments and programming needed for the analysis of trials data. The second group is concerned with surface instrumentation and is largely occupied with the introduction of automatic weather stations for use both on land and at sea, and with the new generation of automatic recording devices which provide data in a form suitable for subsequent analysis by computer. It also contains the electronics section which provides support to other parts of the Branch as well as developing a range of electronic modules for application in many different projects. The remaining sections, which are concerned with the subsequent exploitation of these developments, are grouped together under a Technical Manager who is responsible for the technical progressing of manufacturing contracts, for acceptance testing and calibration of equipment, for installation and finally for maintenance of equipment throughout its working life in the field.

In addition to these main functional groups there are several technical support sections or services which contribute to the furtherance of instrumental projects. The electronic workshop is concerned with the construction of prototypes and, to an increasing extent, with the in-house manufacture of fully engineered pre-production prototypes required for evaluation in operational trials. The mechanical workshop is also concerned with the construction of prototype equipment, dividing its time more or less equally between work for operational and physical-research branches. The engineering drawing office is mainly concerned with the provision of drawings and design data for manufacturers in readiness for production. Because of the wide range of expertise required, extensive use is made of services provided by outside contract firms, including the design of printed circuit boards using modern integrated-circuit components. The section concerned with inspection and acceptance testing of equipment has the responsibility of determining whether deliveries have been made in accordance with the specifications; for complex systems, this is often carried out at the manufacturer's premises. Apart from the contractual aspects, however, the section also subjects new types of equipment to exhaustive environmental testing to avoid the risk of problems arising later during user evaluation in the field. It maintains a standards laboratory with a complete range of appropriate working standards, and is now able to undertake the calibration of all routine meteorological instruments.

As the use, complexity and diversity of equipment have grown, the work of the servicing organization has greatly increased. The basic commitment continues to be the maintenance and inspection of electronic and electrical equipment at home and abroad, but technical staff now carry out some installation and field calibration work and also provide technical support for field trials at outstations. At the same time, operational users are tending to require more equipment to be established at remote sites—automatic weather observing

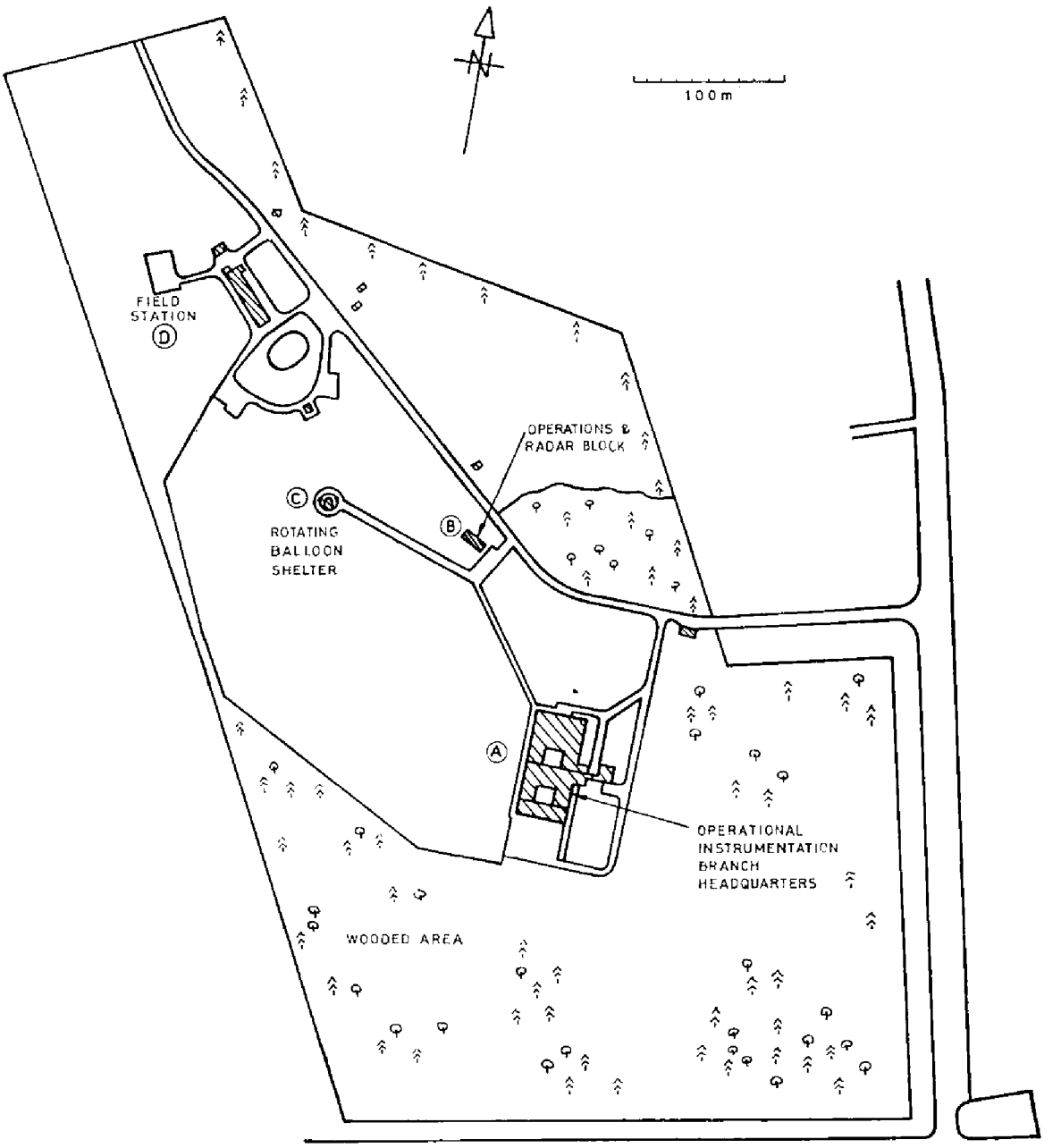


FIGURE 1—BEAUFORT PARK AND ITS SURROUNDINGS

systems and climatological recording systems on land, as well as equipment installed on ships of opportunity, buoys and marine platforms. The work is not restricted to the observational network since technical support is also provided for meteorological telecommunication centres and facsimile networks. Staff are based at over 20 servicing centres and are responsible for equipment at some 300 stations. Much travelling is essential and about 300 000 miles are travelled annually by road, in addition to some journeys by sea and air.

Trainee technicians attend a basic electronics course at Royal Air Force, Sealand, followed by an intensive course at Beaufort Park where they gain familiarity with both theoretical and practical aspects of current instruments and systems. Short courses are arranged for experienced staff to cover equipment which is new to them. The instructors are also involved in studying the

efficiency of servicing methods in the field, and must adapt their courses and training methods to changes which arise from advances in the technology of instrumentation.

Information on equipment faults and design shortcomings is collected from servicing, installation and calibration staff and users, and is processed to meet the needs of designers, manufacturers and post-design services staff. Wherever possible the latter group, in consultation with experts in many fields, deal with the minor problems which arise. More-serious design faults are referred back to the development group which was involved in the original design.

The co-ordination of the preparation of documentation, including specifications, installation instructions, servicing manuals and operators' instructions, is carried out by a small technical writing section. When possible, firms manufacturing equipment are required to produce the technical literature but, when equipment is manufactured by firms which do not have their own technical writers, it is advantageous to supervise directly the preparation, by outside contract firms, of technical manuals for such equipment.

Progress of each major project is monitored and checked against the project plan by using modern management methods such as programme evaluation review technique (PERT). The use of PERT diagrams enables project managers to check the progress of perhaps hundreds of separate activities, and to make recommendations for the redeployment of staff and other resources in order to keep to the time-table laid down for the project.

Methods

In order to reduce the variety of instruments in service, thereby simplifying spares holdings and the problems of servicing, it has been found necessary to evolve a policy of rationalization and standardization for all operational instrumental equipment—whether designed within the Office or by outside industry. One of the first steps was to standardize on a single system for instrumental telemetry; another was to adopt common standards for construction of modules from individual printed circuit boards (PCBs); a further step was to standardize the electrical interfaces between sensors and systems, and between different modules within a system.

In order to obtain the greater reliability needed in automatic equipment required to operate in remote places with very infrequent attention, basic circuits were given more thorough environmental engineering, certain vital aspects of data-recording systems were duplicated, acceptance-testing schedules were made more demanding, and greater weight was given to servicing aspects in the design of this equipment. The quality of individual components used in PCBs is regularly checked, when deliveries are received from suppliers, in order to ensure that design and development staff use only the most reliable components. In this way, a standard list of approved items is compiled and revised whenever necessary.

When a new requirement is put forward by a user branch, the means of acquiring the data to an acceptable degree of accuracy are carefully examined in co-operation with the Observational Requirements and Practices Branch. The most appropriate combination of sensors and observational techniques is selected and the main features of the system which is to telemeter, display and/or record the data are decided upon. Design and development of a laboratory model are followed by construction of the first prototype. After this has been

tried out in the field, and comments obtained from the user, three or four pre-production prototypes are manufactured and these then undergo operational evaluation. By this time, other staff from the installation, servicing, testing and technical writing sections will have been involved, so that the trials can be a test of all the support arrangements as well as of the equipment itself. Trials can take up to two years in some cases, and analysis of the large amounts of data produced is often best done on a computer. These data, more often than not, are the results of comparisons between the existing method of acquiring data and the new equipment under trial.

The nature of projects has changed in recent years as individual instruments have had to be replaced by more-complex systems meeting more-demanding operational requirements. Project teams have become more multi-disciplinary, combining experts in sensors, electronic systems and mechanical aspects; they also work more closely with installation, testing and servicing sections so that planning is not only integrated, but is started earlier in each of the areas concerned. The emergence of some very large projects has required careful phasing of the different stages so that the limited resources of general facilities such as workshops or drawing office do not become over-stretched. The role of the team leader or project manager has also become more important.

Recent changes in instrumentation

The emphasis in recent years has been on the development of equipment to help the human observer wherever possible, to supplement his efforts by the use of automatic or semi-automatic instruments in inconvenient places or at inconvenient times, and to automate the means of processing and recording the data. The challenge has been to acquire data at distances ranging from tens of metres to tens of kilometres, to telemeter these data without loss of accuracy, and to display and/or record the data at a point selected by the user. Some examples are described below.

Electrical-resistance thermometers and tipping-bucket rain-gauges have now come into general use at airfields where readings are required from distant instrument enclosures near the runways with visual displays in the observing office. Recently, lithium chloride hygrometers have been approved for use to provide humidity data in freezing conditions when it is not practicable to maintain a wet-bulb thermometer. The Mk 5 wind system was developed to telemeter data over considerable distances and to provide the numerous displays required at large airports by meteorologists and air traffic controllers. The use of normal telephone links avoids the problems and costs of laying special-purpose cables. Additional features were also developed for the Mk 4 wind system. These include automatic range-change devices to prevent the anemograph trace going off scale in severe gales, and runway cross-wind resolvers to provide air traffic controllers with a direct indication of the wind component at right angles to any selected runway.

The continuous automatic remote display (CARD) system permits signals from several sensors to be sampled and telemetered over a single telephone link to a distant display point. Rapidly changing elements, such as wind, are sampled more frequently than slowly varying elements, such as temperature, and the data are reconstituted in such a way that the remote display is indistinguishable from the normal continuous records. Although the input and output signals are often analogue in character, the telemetry process

itself is digital and this prevents loss of accuracy over long lines. This new system will be of benefit to offices which have to provide forecasts for satellite airfields where hitherto there have been no observations. It is particularly suitable for use with cloud-base recorders and transmissometers.

The first 10 of the new generation of automatic weather observing systems (MOWOS) are now undergoing operational evaluation (see Plate I). There are two main components of these systems: a remote field station where the observations are made, and a receiver where the data are displayed. Any forecast office with MOWOS receiving equipment can dial any MOWOS observing station in the network, by using the public telephone system. The data are updated and stored at the observing unit every 5 or 10 minutes and a typical transmission, including checks for corrupt data caused by line interference, takes about half a minute. Some of the sensors have been specially developed for use with MOWOS; these include a rate-of-rainfall detector and an electronic detector of bright sunshine to give the forecaster some idea of 'present weather'.

For climatological purposes tipping-bucket rain-gauges and magnetic-tape event recorders are now being used to acquire rainfall data. Pulses indicating time and rainfall events are each recorded on two tracks of a four-track, quarter-inch magnetic-tape recorder. The tape is moved on one step when a pulse is received, 200 steps occupying one inch of tape. The tapes, which are in cassettes, are usually changed once a month, although the battery-operated equipment will run satisfactorily for up to three months if required. Complete cassettes are taken to the central translator in Bracknell where the data are converted on to punched paper tape ready for input to the IBM 360/195 main computer. This new rain-gauge system enables the fine structure of rainfall to be recorded in areas where only daily totals were previously available, and also removes the need for laborious extraction by human analysts of detailed data from the former autographic traces.

The development of other magnetic-tape recorders is nearing completion: one of these will replace the original data logging equipment (MODLE) which recorded solar radiation and other data on punched paper tape. Another is the digital anemograph logging equipment (DALE) which automatically calculates mean wind values and highest gusts, and records these hour by hour. Tapes from these devices will be translated by the computerized translation facility set up by the Systems Development Branch.

In the marine field, the small experimental telemetering buoy, OBOE I, has been successfully used in the Irish Sea and in the mouth of the Thames Estuary. An operational version of this buoy, to be known as OBOE THAMES, is due for launch next year. A medium-sized buoy, OBOE II, provided by the Royal Navy, is now being instrumented and will be used initially in the Irish Sea and later, possibly, in the south-west approaches of the Celtic Sea. The Branch has designed, and is providing, the meteorological sub-system for the large U.K. national data buoy, DB I, which is due for launch next year. This will be used in the North Sea about 50 km from Lowestoft in the first instance. The Branch is also involved with three other departments or institutes in equipping several small drifting buoys for use in the North-east Atlantic. These will be located, and their data relayed, by the U.S. experimental weather satellite NIMBUS F to be placed in orbit in 1975.

The new Mk 3 radiosondes, which are due to come into operational service

in 1976, have shown in recent international trials that their performance is equal to that of special reference sondes. The very considerable problems of devising computational routines, whereby data could be fed to an on-line computer and processed in real time to provide fully coded meteorological messages, have been overcome. In parallel with this activity, the network of upper-air observing stations has been completely re-equipped with modern wind-finding radars having greatly increased range, and more recently these radars have been fitted with data print-out units capable of linking the radars to the Mk 3 radiosonde ground-station computer. A similar computer will also be used at the heart of a new automated central calibration plant at the Eastern Road site. Both there, and at the upper-air observing stations, it will be possible to achieve useful staff savings. Improved neoprene balloons have become available which are capable of attaining heights of around 30 km before bursting. These will enable advantage to be taken of the improvement in accuracy provided by the Mk 3 radiosonde which is particularly noticeable at these heights.

Some instruments under development or evaluation

Development of the instruments and systems described in the previous section has been completed, and for the most part the equipment has been manufactured and is already entering service. Many new developments are under way, however, and some of these provide interesting examples of more-recent trends in modern instrumentation.

A Mk 6 digital temperature indicator has been developed for use with electrical-resistance thermometers. This will not require to be set by hand, as with the present Mk 5 temperature bridge, but will give a direct reading in degrees and tenths Celsius. It is hoped to commence operational trials of this during 1975. The electronic transducer responsive to sunshine originally developed for use with MOWOS, to provide the forecaster with some idea of state of sky, will also undergo trials with a view to providing the climatologist with duration of sunshine at automatic climatological stations. A complementary state-of-sky detector, based on radiometric principles, is being developed for use with MOWOS at night. Several visibility sensors which are simpler, cheaper in themselves, and more economic to install than the standard transmissometers are undergoing detailed investigation for possible use with remote observing and display systems such as MOWOS and CARD on land, and on marine buoys and platforms. Preliminary experiments are also being planned to interrogate the MOWOS network direct from a central computer, and to code the meteorological messages automatically.

The choice of the most suitable type of replacement for the present generation of cloud-base recorders lies between a rotating-beam instrument, having improved optics and making use of electronic function generators in place of mechanical cams, and a laser cloud-base recorder. The latter is potentially more accurate but the present safety criteria require that the laser should be of very low power and this necessitates rather complex signal processing. Whichever instrument is finally selected, improved visual displays will be provided to give a clearer picture of the amount of cloud in each significant height range, and these may contain sufficient information when the cloud-base recorder is situated at a 'guard' station, rather than at an airfield, to give early warning of changing conditions.

Reference has been made elsewhere to the development and construction

of a medium-sized buoy, OBOE II. Since the sensors, superstructure, electronics, radio equipment and power supplies form an integral package which in this particular application is then attached to the OBOE II hull, it is possible to regard the package as a marine automatic weather station which is available for mounting on other platforms of opportunity. It might, for instance, soon be practicable to take up a previous offer, by Trinity House, to have meteorological instruments mounted on large automatic navigation buoys. Another project is the meteorological observing system for ships (MOSS), which involves the development of semi-automatic equipment based on the CARD system. It will be possible to display instrumental data at a point convenient to the ship's officer making the observation.

Future prospects

It would not be appropriate in this article to do much more than indicate the broad direction of future changes in the concept or application of instrumentation for operational meteorology. Automatic weather observing systems will be used increasingly to fill gaps, in both time and space, in the existing observational network and micro-processers are likely to be used to link these direct with central computers. One of the reasons for the appearance of those gaps is the loss of co-operating observers. Economies and schemes of automation in other fields have already resulted in a reduction in observations which have been a useful and important source of data in the past. Examples are the replacement of light-vessels by automatic light-towers or light-buoys, the automation of lighthouses and the closing of airfields.

It is probable that specialized networks will be established for particular purposes; this is now a technical possibility because automatic means of acquiring data permit networks to be designed with less regard to existing stations or facilities. For example, C-band (5·6 cm) weather radars used in conjunction with a small number of calibrating rain-gauges may be used to acquire quantitative data on rainfall, and synoptic data on significant mesoscale developments. There will probably be a gradual development of these for unattended use so that, for instance, it would be possible to establish a national coverage with about 10 or 12 radars. These could be linked to, and controlled by, a central computer and the results presented in composite form to forecasters and other interested parties such as the new Water Authorities. Other possible developments in the context of mesoscale networks are concerned with the use of remote-sensing techniques to acquire observations in the atmospheric boundary layer.

The climatologist will be able to design and establish suitable networks of instruments using battery-operated loggers in remote areas as required and, since the data will be in a form where automatic processing by computer becomes a routine operation, the task of assimilating the data should be largely overcome.

At sea, there is likely to be an attempt to provide or increase observations in the data-sparse areas. Semi-automatic acquisition systems will be used more extensively on ships of opportunity to help the hard-pressed observers, and it is possible that satellites may eventually be used to relay the information to meteorological centres, particularly when there is no radio officer on watch or where there are inadequate ship-to-shore links. Wind-finding equipment using navigational radio techniques to plot the movement of a target moving

with the wind will probably be used on ocean weather ships, and a variety of automatic equipment will be used on moored or drifting buoys and fixed marine platforms to provide a better observing network over the oceans.

The continued development of modern meteorological instruments, systems and techniques for use on the earth's surface or in association with surface-based stations holds much promise for further improvements of the meteorological observing system. When this is considered in association with further developments of satellite-based meteorological observing systems and techniques the prospects for improved meteorological observations are very promising.

Forecasting Services

Central Forecasting Office

Bracknell is a Regional Meteorological Centre (RMC) within the framework of World Weather Watch (WWW). The latter is a concept ratified by the Congress of the World Meteorological Organization (WMO), whereby the meteorologically more advanced nations assist the less advanced. This assistance is achieved by the establishment of three World Meteorological Centres at Washington, Moscow and Melbourne, and by a number of RMCs. The Central Forecasting Office (CFO) at Bracknell has undertaken to meet stated needs of various National Meteorological Centres (NMCs) in Europe for regional forecasts. This it does by the preparation, for wireless-telegraphy and radio-facsimile transmission, of analysis and forecast charts covering a large area of the North Atlantic, Europe and the Arctic.

In addition to its role as an RMC in the World Weather Watch, CFO is also the chief forecasting office for the national meteorological service and the ways in which it supports these roles are described fairly fully below.

The Central Forecasting Office continued to make considerable use of the computer output from the 10-level numerical forecasting models, the basic procedures remaining similar to those described in the *Annual Reports* for the past two years. Refinements were introduced as a result of continuing research work.

Before a numerical forecast can be made, the computer is used to prepare an objective analysis of the initial data. Experience has shown that this analysis can be improved by human intervention, which compensates for some of the shortcomings of the observations available. Following a detailed review of the work of CFO, the intervention team was strengthened late in the year so as to provide greater effort on this important aspect of the operational work. The intervention includes modification or rejection of some of the data, the addition of data based on information relating to non-standard times, and the inclusion of late or corrected observations. These activities are needed in order partially to offset the effect of the withdrawal of the U.S. weather ships from the western Atlantic, the loss of which has not been fully compensated by the use of satellite information. The enlarged intervention team will be able to provide intervention for the fine-mesh version of the 10-level model, which covers a rectangular area designed for detailed weather forecasting over the British Isles, as well as for the coarse-mesh version, which covers an octagonal area embracing much of the northern hemisphere. Computer programs have been developed to permit intervention on the background and analysed fields by means of the

visual display unit (VDU) in CFO. These facilities will be brought into operational use when more experience with them has been gained, and when the enhancement of the computer complex makes the VDU available whenever required (see page 47).

In 1973 a more efficient computational scheme, the so-called semi-implicit integration method, was prepared by the Forecasting Research Branch for use with the fine-mesh version of the 10-level model; during 1974 a comparable scheme for the coarse-mesh octagon version of the model was produced and was brought into operational use from the end of October. With computer time at a premium the saving of time was a major consideration; but of equal importance was the ability to restructure the operational runs within the previously accepted ration of computer time for operational use, to permit a better service of computer products to the CFO forecasters, and to match the computer advice to the operational need more effectively.

Development of the comprehensive three-dimensional scheme for objective analysis using orthogonal polynomial fitting was continued in 1974 and it was found possible to introduce this scheme operationally at the end of July for an extended period. Subsequent changes have been made to improve the quality of the analysis and also to reduce the computer time used. The experience gained in running the three-dimensional scheme operationally should advance the development of the linked four-dimensional analysis scheme. Vertical temperature profiles derived from infra-red measurements from satellites and aircraft reports at several levels have both been introduced into the objective analysis during the year, although no account is yet taken of the fact that most of these data are not for the standard synoptic times. As the amount of data at non-standard times is increasing at the expense of data made at standard times, it is essential to maintain the effort to develop such a four-dimensional scheme, in order to derive as much benefit as possible from sophisticated atmospheric models such as the 10-level model.

Use is made in CFO of automatically plotted charts but the manually produced hourly charts disseminated on facsimile cannot be replaced by automatically plotted charts until a second Calcomp 1670 microfilm plotter is installed, thereby ensuring a 24-hour service which can be maintained even when there is equipment failure, and until the hourly data are channelled more effectively through the communication links to the IBM 360/195 computer. Both these requirements seem likely to be realized in the near future.

The main tasks of CFO remain much as in recent years and the general pattern of work in 1974 followed that described in the *Annual Report* for 1973. Computer analyses and prognoses for levels other than the surface continue to be issued in unmodified form on a number of facsimile land-line and radio circuits, both to domestic and to foreign recipients, though modifications are still made by the section monitoring the upper-air prognoses and aircraft reports during the production of flight documentation for civil aviation.

The Senior Forecaster's tasks listed in the *Annual Report* for 1973 continued almost unchanged as did the routine issues of forecasts for sea and land areas, together with notifications of expected specified weather or warnings of hazardous conditions. The issue of analyses and prognoses of wave height and direction for the North Atlantic area have received favourable comment from marine interests, as has the daily chart giving the analyses of ice conditions over the North Atlantic, Baltic, Scandinavian and Arctic waters. Isotherms of sea surface

temperature are given on these ice charts as well as on separate charts for the coastal waters of the British Isles.

The organization for the ship routeing service, which is described under 'Services for marine activities', was changed slightly during the year and Nautical Officers now have a greater responsibility for the preparation of the advisory messages. Within CFO the tasks of giving meteorological advice to the Nautical Officers and preparing wave forecasts were transferred to the section, suitably augmented, responsible for medium-range guidance (up to 3 days ahead).

The section within the Central Forecasting Branch which is responsible for the operational numerical weather-prediction computer programs has introduced a number of changes during 1974 designed to improve the quality of computer products for CFO and for several other users. Attention has been given during the year to the organization of the operational suites of programs and a considerable streamlining has been achieved. The section is responsible for the already mentioned development of objective analysis techniques and visual display unit facilities. Among the many output products from the operational suite, particular mention may be made of data which are transmitted to users in Belgium in a WMO code using grid-points. Close co-operation with the Forecasting Research Branch has remained an important feature of the work, as for example with the introduction of the semi-implicit integration scheme into the coarse-mesh 10-level-model forecast. During 1974 the coarse-mesh-model forecasts were experimentally extended to obtain a six-day forecast once each week.

It was also found possible for a combined experiment to be run with the Forecasting Research Branch to assess the effects of loss of data from the North Atlantic weather ships and the inclusion or exclusion of the large amounts of data now becoming available from satellites.

CFO continues to be responsible for the publication of the *Daily Weather Report* (*DWR*) with its *Overseas Supplement*, the *Monthly Summary* and the *Daily Aerological Record* (*DAR*).

In the international field the Assistant Director (Central Forecasting) serves as a member of the Working Group on the Global Data Processing System (GDPS), one of the working groups of the WMO Commission for Basic Systems; he also acts as the Meteorological Office Co-ordinator for the pilot study group for the Integral Global Ocean Station System (IGOSS) Bathy Pilot Project.

Services for industry, commerce and the general public

Forecasting services for industry, commerce and the general public are provided directly by the Weather Centres and by a number of other forecasting offices, or indirectly through radio, television, the Press and the Post Office's automatic telephone weather service. Most of the work is undertaken by some 37 offices distributed throughout the Kingdom. Their telephone numbers are published in the preface to area telephone directories, the *Post Office Guide*, official leaflets and many trade journals. Another 50 or so unpublicized offices also handle a considerable number of requests for advice from industry and the public and contribute significantly to weather services for the community.

The opening of an office at Royal Air Force, Brawdy, near Haverfordwest, in September led to an expansion of the facilities available to the public in west Wales and increased to four the number of offices in Wales providing services for the community.

Following the marked increase in the public demand for weather advice in 1973, when inquiries reached a record total, 1974 proved an even more demanding year with direct inquiries to forecasting offices reaching an all-time record of 1 854 387. The poor weather during the main harvesting and holiday season generated a huge increase in demand in the agriculture, holiday and marine sectors and the total of 215 000 inquiries in August was well above the previous highest-ever monthly total recorded in February 1969, a month of exceptionally severe winter weather. The concern expressed in the 1973 *Report* about the growth of casual inquiries during the summer months and the conflict with other work remains. The number of staff employed by the Office is strictly limited and members of the public may find access to a forecaster increasingly difficult at peak periods.

Calls on the Post Office's automatic telephone weather service during 1974 also reached a new record total of 16 255 932 as against 15 501 162 in 1973. Several experimental changes were made during the year with the joint aims of improving Post Office profitability and making a local forecast available on a much broader basis than before. To this end, in place of three separate forecasts for south Lancashire and north Cheshire, the Lancashire coast, and central Lancashire, a single forecast was issued covering the whole of Lancashire, Cheshire, Greater Manchester and Merseyside. Of necessity, the forecast is rather more general than hitherto. Similar changes were made in the south-west and the north-east of England, where the forecasts now cover the whole of Devon and Cornwall and north-east England respectively. Public reaction to these changes has been minimal. Again in 1974, by local arrangement, forecasts were provided in connection with a marine information service operated in the Swansea telephone area in the summer months, and for a ski-report service operated in the Edinburgh telephone area during the winter. Preliminary discussions were held with the Post Office with a view to expanding this type of information service, perhaps to include special recorded forecasts for yachtsmen in certain areas.

The dissemination via television and radio of routine forecast information and warnings of severe weather continued, with some important changes in detail. As far as BBC Television was concerned, the early-evening presentation on BBC 2, in which the forecaster out of vision presented the forecast on weather maps which were in vision, was, for technical reasons, replaced in early January by a summary chart and script read by an announcer. A more welcome change, coinciding with the introduction of the autumn broadcasting schedules, was the move of the 'close-down' presentation on Monday to Thursday to a more popular viewing spot after the Late Night News, as was already the case on Friday. During the summer months the Friday evening presentation was extended to include an item on continental holiday weather. Services to the independent television companies continued largely unchanged, but several companies displayed a growing interest in a lunch-time presentation to complement their early-evening and late-night presentations.

Services on Radio 4 (Wales) were improved by the addition of a special weather forecast for Snowdonia for broadcast in the Saturday morning edition

of 'Good Morning Wales'; reports of actual weather at a number of locations in Wales were also supplied daily, Monday to Saturday, for broadcast during this programme. Only minor changes were made in other services to BBC national radio.

BBC local radio continued to take full advantage of the meteorological services available. Radio Leeds and Radio Nottingham increased their 'live' presentations by a forecaster from one to two per day and, for the first time, Radio Stoke-on-Trent commenced a 'live' presentation; these were in addition to the service of scripted forecasts read by an announcer.

The situation with regard to commercial radio has been disappointing. Only three of the seven commercial stations in operation in 1974 contracted for meteorological services, the remainder declining a service on financial grounds.

A large number of broadcasts and interviews were given by members of the staff on radio and television, most of them concerning current weather, but the remainder covering a variety of topics. Two staff members participated in a Radio 4 programme in the 'Friday Call' series, to answer questions from listeners on a wide range of meteorological topics; the same members were also interviewed on the subjects of the British climate and the problems of weather forecasting for a programme in the 'Context' series on Radio 3. Several recordings were made for broadcast in programmes for schools, including one for the Bavarian State Radio Network. Members of the staff at London Weather Centre and London/Heathrow Airport contributed to a Radio London programme in a series sponsored by the Department of Employment describing the occupations of Londoners and those who work in and around London.

The Office provided facilities for the filming of various aspects of its work by the BBC and independent television companies. A team from Ulster Television filmed the work of the forecasting office at Aldergrove and the radiosonde station at Long Kesh; a team from BBC Norwich filmed the work of the office at Honington for inclusion in the 'Look East' spot on BBC 1 'Nationwide'; BBC Plymouth made a short film in the office at Plymouth for broadcast in 'Spotlight Southwest'; and several teams visited Bracknell during the course of the year to film in the Central Forecasting Office (CFO), the Telecommunication Centre and the Computing Laboratory. A lively interest was shown in the role of the Hercules research aircraft of the Meteorological Research Flight in the GARP Atlantic Tropical Experiment, prompting a visit to Farnborough by the BBC TV science correspondent and camera crew to film the aircraft and interview staff members; this film was also shown on Australian Television, a suitable introduction being recorded at Bracknell by representatives of the Australian Broadcasting Commission.

The Office also co-operated with the Central Office of Information in the preparation of a five-minute report on the work of the Office as part of a regular weekly series broadcast on television in Australia, New Zealand, Canada, Mexico, South America and a number of other English- and Spanish-speaking areas all over the world.

Services to the Press continued as in previous years, but changes were made in the Press Forecast Districts to conform with the changes in county boundaries and designations which became effective on 1 April. As usual, many requests were received from the national and provincial Press for special interviews and comment on a variety of topics.

Special services tailored to meet requirements were, as in previous years, provided for the British Gas Corporation, the Central Electricity Board, British Rail, London Transport and many smaller concerns.

Other special services included warnings of road dangers due to weather to highway authorities during the winter months, forecasts for pigeon racing, the notification of fine spells to farmers, and advice on week-end temperatures to assist those responsible for the heating of industrial and other premises in winter. No less than 328 highway authorities and others registered for the road danger warning service and 89 pigeon organizations took advantage of the service for pigeon racing. Demand for the fine-spell service continued to decline, largely, it is thought, because the information is readily available in routine forecasts. The responsibility for providing week-end temperature forecasts for industry was transferred from CFO to regional forecasting offices. This permits the inclusion of more-detailed local information and, it is hoped, will encourage beneficially direct contact between the user and the forecaster.

The Weather Centres at London, Glasgow, Manchester, Southampton and Newcastle and the public service office at Watnall, near Nottingham, handled the greater part of the work in the public sector. Excluding weather maps provided for shipping at certain major ports, the total numbers of inquiries dealt with over the past three years are shown below:

	London	Glasgow	Manchester	Southampton	Newcastle	Watnall
1972 ..	313 024	89 770	116 914	93 532	81 889	57 483
1973 ..	309 453	109 941	131 593	96 868	94 658	62 415
1974 ..	313 784	112 293	123 148	97 317	98 223	59 461

Grand totals: 1972, 752 612; 1973, 804 928; 1974, 804 226.

The general public continued to express a lively interest in the work of the Office. Some 103 parties visited the Headquarters during the year and were shown the work of the Central Forecasting Office, the Telecommunication Centre and the Computing Laboratory; of these, 20 were from overseas representing 14 countries, including Argentina, Australia and the People's Republic of China. A further 19 visits were arranged for representatives of the Press and various broadcasting authorities. At the Weather Centres and Watnall some 90 parties from universities and schools were shown the work of the various offices. Many requests were received for lectures and talks to be given to outside bodies and over 100 were given voluntarily by members of the staff during the year.

Services for the general public (overseas)

Forecast services were provided through the media of Press, radio and television in Gibraltar, Malta and Cyprus and special services were provided for public utilities and such engineering consortia as those responsible for offshore oil-drilling rigs at various locations.

Services for marine activities

General services to shipping via BBC radio and the Post Office coastal radio stations continued as in previous years, but to avoid conflict with the

international 'silence' periods the times of broadcast of the first two bulletins of the day on Radio 2 were changed to 0033 and 0633. A proposal to change the order of the coastal-station reports in the bulletins was referred to the Department of Trade for consideration by the industry.

A meeting was held with representatives of the Scottish Inshore White Fish Producers' Association Ltd in October to discuss proposals to alleviate the problem of poor reception of the shipping bulletins in certain sea areas around Scotland. It was agreed that a gale-warning summary for all sea areas north of 55°N would be added to the Radio 4 (Scotland) Inshore Waters Forecast pending a longer-term review of the whole problem.

Special marine services provided by the London Weather Centre continued to increase. In addition to routine responsibilities for the Port of London Authority, the Centre specializes in forecasts requiring detailed wave information over any part of the North Sea and the coastal sea areas around the United Kingdom. Thus, forecasts were prepared for tanker-lightening operations, mostly in the English Channel, and for a wide range of marine activities from dredging to the construction of jetties and sewage outfalls. The major work-load of the Centre is, however, for the offshore oil industry, which is now extending its operations from the central North Sea to areas north and west of Shetland and into the Irish Sea. Detailed forecasts for up to 72 hours ahead are supplied for exploration rigs, production platforms, survey and supply vessels, pipe-laying barges and the civil engineering companies concerned with construction work at the new oil fields. By October 1974, forecasts were being provided for no less than 45 individual locations, more than twice the number being supplied two years ago, in October 1972.

The main meteorological office at Pitreavie continued to provide a winter forecast service for the benefit of North Sea fishing vessels; forecasts are issued daily from October to March, covering a 72-hour period.

Forecasts for Royal Navy ships are supplied by Pitreavie and Plymouth/Mount Batten offices and for Royal Air Force marine craft at home and abroad by the nearest meteorological office.

The office at Plymouth provided special forecast services for the Royal Ocean Racing Club for the One-Ton Cup races in Torbay in July.

The increasing interest in yachting and other marine sports was reflected in the substantially increased number of inquiries for weather information for inshore waters and out to sea. The special week-end sailing forecast and chart issued by Southampton Weather Centre every Friday afternoon during the summer months again proved very popular. Over 9000 charts were distributed to marinas, yacht clubs and individual yachtsmen on a repayment basis.

Ship routeing services are provided for the North Atlantic and North Pacific Oceans, about 200 ship routeings being made for the former and 54 for the latter. The requirements which have to be satisfied when guidance is given on the advisory routes or courses to steer depend upon a variety of factors, namely the type of vessel and cargo, operating costs, etc. In general the crossing is required to be achieved in as short a time as possible compatible with the need to avoid weather and wave conditions liable to cause damage to the ship and its cargo. The operating costs of oil tanker companies are very high and therefore the normal requirement of such companies from the routeing service is for the least-time passage. An added consideration over the last year is the

fact that operating costs have rocketed due to fuel price increases, and the need to conserve fuel by running at the most economical speed has to be taken into account.

In order to predict the speed of a vessel in the wave patterns it is expected to experience, it is first necessary to know beforehand its performance in various states of sea. To obtain this information a Nautical Officer of the Ship Routeing Service visits, if possible, the ship before its first routed voyage and extracts data from the ship's log-books to enable him to draw graphs of the ship's performance in relation to the wave height for various relative directions of approach between ship and waves, i.e. waves from ahead, abeam or astern. Subsequently when the ship is being routed, the speed is calculated along various possible courses in relation to the predicted wave patterns and some regard is also given to the general conditions in the outlook beyond 48 hours ahead. The main features of the general atmospheric circulation are also taken into account in arriving at the advice to be given to masters, particularly on the North Pacific, where voyages usually last about three weeks. A number of other factors such as the likelihood of fog or ice, and the direction and speed of ocean currents are also taken into account. Normally the master is contacted by telephone in the U.K. port shortly before sailing, and regular advice and forecasts are sent to him thereafter at least as frequently as every 48 hours through the Post Office transmitter at Portishead, near Bristol.

The Central Forecasting Office (CFO) is responsible for supplying guidance forecasts and warnings to the Department of Trade's fisheries mother-ship which is stationed off the Icelandic coast during the winter to provide weather information as well as medical and repair services for British trawlers operating in that area. Normally the link between CFO and the trawlers is a forecaster on board the mother-ship: this forecaster provides the detailed forecasts for the trawlers by using CFO guidance and warnings of gales, storms and ice accretion and he also keeps CFO informed of conditions in the fishing area by means of a regular series of observations.

The shipping forecasts broadcast four times a day by the BBC and the gale warnings prefixed 'attention all shipping' originate at CFO and are of course very well known, receiving considerable publicity on the occasion of the loss of the yacht *Morning Cloud*. Lesser-known services which CFO provides for marine activities include forecasts for oil-drilling ships and for movements of oil rigs from one area to another. The routine forecasts to North Sea oil rigs emanating from London Weather Centre also rely upon the guidance and warnings issued by CFO. Oil slicks and pollution at sea are also emergencies in which CFO plays its part in issuing forecasts and advice.

CFO works closely with the officers of the Storm Tide Warning Service who are responsible for issuing alerts when flooding on the east coast of England is possible due to the effect of strong winds causing unusually high tides. Warnings of tropical hurricanes, cyclones and typhoons were issued to Lloyd's when appropriate.

Services for civil aviation

Meteorological Services for civil aviation in the United Kingdom are provided by the Office as an agent of the Civil Aviation Authority.

Civil aviation forecasters within the Central Forecasting Office (CFO) at Bracknell are responsible for the preparation of forecasts of upper winds and

temperatures required by civil aviation. They use data processed by the Meteorological Office computer. These forecasts, together with forecasts of significant weather prepared at London/Heathrow Airport, form the basis of flight documentation distributed to major airports throughout the United Kingdom and Europe. Distribution within the United Kingdom is by the civil aviation facsimile network (CAMFAX), the hub of which is in the meteorological office at Heathrow. Charts of forecast upper winds and temperatures for levels from 5000 to 40 000 ft ($\approx$ 1500 to 12 000 m), significant weather and tropopause height are broadcast by CAMFAX every six hours to cover flights to destinations in Europe, the Mediterranean area, Canada, U.S.A. and the Caribbean region. Meteorologists at airports add information concerning take-off and landing conditions to complete the flight documents which are presented to aircraft captains at pre-flight briefings.

The Principal Forecasting Office at Heathrow is designated the European Area Forecast Centre for all flights to the U.S.A., Canada and parts of the Caribbean from departure airports in Europe. Flight documentation for these flights is passed by land-line facsimile to Dublin, Paris, Frankfurt, Rome, De Bilt and Copenhagen and by radio-facsimile to more-distant recipients.

Routine half-hourly observations of weather are made at all major civil airports in the United Kingdom as part of the network of airport weather reports continuously exchanged between airports throughout Europe and the Mediterranean area over discrete civil aviation teleprinter circuits.

Meteorological services for general aviation (private flying, air taxi services etc.) are provided on request by local civil and RAF meteorological offices. This type of service is specialized and calls for detailed assessments of cloud, visibility, low-level winds and weather hazardous to light aircraft. An operational trial continued throughout the year of a service—the general aviation visual flight service—providing recorded forecasts of flight conditions in each of a number of defined subdivisions of England and Wales. Each area is given a coding which indicates whether flight under visual flight rules is appropriate and these forecasts are available from published telephone numbers.

The Meteorological Office computer continued to provide 18- and 24-hour forecasts of winds and temperatures at about 35 000 ft ($\approx$ 11 000 m) twice daily for British Airways, Overseas Division (formerly BOAC), in a grid-point format for use in the preparation by the airline of computerized flight plans. Similar data were provided for Shanwick Oceanic Control at Prestwick.

Special forecasts for supersonic flights by Concorde aircraft have been supplied from Heathrow to the Concorde Forecasting Office at Fairford.

In April and May the International Civil Aviation Organization and the World Meteorological Organization Commission for Aeronautical Meteorology held two meetings conjointly in Montreal—the 8th Air Navigation Conference and the Meteorological Division Meeting. Members of the Office were included in the U.K. delegations to both meetings where regulations concerning the provision of meteorological services for civil aviation were reviewed and brought up to date.

Services for civil aviation (overseas)

Services for civil and general aviation continued to be provided at Wildenrath, Gütersloh, Gibraltar, Luqa, Nicosia, Masirah and Salalah but Nicosia

Airport was closed in July as a result of the Cyprus emergency. The various civil aviation authorities were supplied with technical advice on various problems which arose during the year.

Services for the Royal Air Force

A senior officer of the Meteorological Office is located at each of the following RAF Command Headquarters: Strike Command, Near East Air Force and RAF Germany. This officer acts as adviser in meteorological matters to the Air Officer Commanding-in-Chief and as liaison officer between him and the Director-General of the Meteorological Office.

Although most of the meteorological offices have multi-role functions, the forecasting services for the Royal Air Force at home continue to be provided by offices which are distributed largely in conformity with the RAF organization. There is a Principal Forecasting Office at Headquarters Strike Command and Main Meteorological Offices, functioning throughout the 24 hours every day, are located at various centres to control and advise subsidiary offices which are located at aerodromes and enable them to meet various requirements of aircraft of many types operating in many different roles. At the subsidiary forecasting offices, a forecaster is on duty at times which depend on the stated requirements of the Royal Air Force.

Maximum use is made of the technical support which is provided by the large computer system at Bracknell. At Headquarters Strike Command and No. 46 Group a comprehensive six-hourly programme of preparation and issue of area and route forecasts in chart form is maintained as routine to meet most operational requirements. These routine issues include a forecast surface-analysis chart and a significant-weather chart in addition to upper-air forecasts for standard levels. The charts are distributed by land-line facsimile to the subsidiary offices where they are duplicated for issue to the aircrews at pre-flight meteorological briefings. As far as possible, the flight documentation is made available in self-briefing format.

Mobile meteorological units are established to support Royal Air Force and Army elements participating in certain field exercises in the United Kingdom and overseas. Each unit has its own air-transportable sets of meteorological and communication equipment for use at locations which are removed from permanent meteorological offices. The facilities include radio-teleprinters, radio-facsimile recording equipment and special apparatus for receiving satellite cloud-pictures. Forecasters in the mobile units hold commissions in class C.C. of the Royal Air Force Reserve of Officers. Special techniques have been evolved for dealing with the forecasting problems which arise in this type of operation.

Offices were opened temporarily for short periods at certain locations to provide a service during large-scale exercises and special operations etc. A forecaster was detached to Barksdale, Louisiana to provide meteorological support for the RAF team competing in the USAF Bombing and Navigation Competition.

Meteorological officers continue to give regular courses of instruction at a number of schools in Training Command and to some Operational Conversion Units. The RAF team which was formed to prepare programmed instruction training packages on meteorology for use at RAF schools has nearly completed

its task and this new system of instruction is to be introduced at some of the schools in 1975.

The Meteorological Office provides technical advice concerning the installation of runway visual range systems at RAF airfields and subsequently calibrates each system every six months.

A military VOLMET broadcast of plain-language weather reports for major RAF aerodromes was continued. This broadcast is provided mainly to meet the needs of transport aircraft returning from overseas to bases in the United Kingdom.

With a view to effecting an economy in manpower a study was made of the meteorological service at RAF airfields in the east of England. As a result the Main Meteorological Office located at Manby was disbanded and its responsibilities distributed between other major offices in the area.

The pattern of meteorological services for the Royal Air Force overseas also conforms closely with the organization of the two major RAF Commands overseas. In the Federal Republic of Germany there is a Main Meteorological Office at Rheindahlen which controls and advises subsidiary forecasting offices at the RAF airfields as well as the newly opened subsidiary office at the Army Aviation Station, Detmold. Similarly the Main Meteorological Office at Episkopi supports subsidiary offices on RAF stations in Cyprus and in Muscat and Oman. There are also Main Meteorological Offices in Gibraltar, Malta and Gan.

During the Cyprus emergency in July and August many problems affecting the operation of the meteorological service were encountered and it was found necessary at one stage to detach extra staff from the U.K. for a short time to supplement locally employed staff who were unable to continue with their duties.

Much of the forecasting at overseas stations is for long routes and for areas largely devoid of observational data. The Central Forecasting Office at Bracknell provides strong technical support for Europe and the Mediterranean area, chiefly by land-line and radio broadcasts of data by teleprinter and charts by facsimile. To augment this support further, overseas stations also have to make use of additional data which are collected locally. Additionally, all the six Main Meteorological Offices have been instrumented to receive cloud pictures from U.S. weather satellites. In Malta, Cyprus and Gan these are supported by powerful weather radars. A network of thunderstorm location (SFLOC) stations, linked to the U.K. network, is established in the Mediterranean. This supplementary information continues to be of the utmost importance to the widely scattered overseas stations.

Services for the Army and Establishments of the Procurement Executive, Ministry of Defence

The Army and MOD (PE) units continued to show an increasing awareness of the need for meteorological support in their planning and operational roles and the increase in the work which was reported last year has been sustained.

During the year a forecasting office for Army Aviation was opened at Detmold, Germany, to meet the growing demands of a number of Army landing grounds. A meteorological officer also continues to be attached to the Headquarters No. 1 (BR) Corps, Bielefeld, Germany, to provide professional

advice for the General Officer Commanding and his staff. The officer, suitably supported by additional staff and communications, takes full part in exercises in the field from time to time.

Development of the Army Meteorological System (AMETS), which is an automated system for the measurement and processing of upper-air data for ballistic purposes, has continued. In particular, the computer program has been modified to meet present requirements. Advice has also been given on the planning, testing and development of a mobile hydrogen generator for use with AMETS.

Offices were maintained at the Royal School of Artillery, Larkhill, and at the Proof and Experimental Establishments at Shoeburyness, Eskmeals, Aberporth and Pendine. Noise (acoustic) assessments are made at Shoeburyness, Eskmeals and Larkhill. The office at Shoeburyness also caters for the meteorological requirements of the Atomic Weapons Research Establishment, Foulness.

Members of the staff of the Office were attached to the Army practice camps at Sennybridge and Otterburn to provide meteorological information for ballistic purposes during exercises on several occasions through the year.

Plans to open a new forecast office at Spadeadam reached a fairly advanced stage early in the year but progress on this project was suspended pending a decision on the future of Shoeburyness, where work in the meantime continues unabated.

Liaison with the Navy Department

The need for the co-ordination of plans to meet the meteorological requirements of defence forces at home and overseas has continued to require close co-operation with the Directorate of Naval Oceanography and Meteorology.

International defence services

The co-ordination of the international meteorological support required by the military forces, and of the study of any associated problems, is undertaken by the various meteorological planning committees of the international defence organizations NATO, CENTO and SEATO, to which the United Kingdom belongs. The Meteorological Office has participated actively in the work of both the NATO and CENTO meteorological committees during the past year.

Services to the Home Office

The meteorological requirements of the Warning and Monitoring Branch of the Home Office have been kept under review in close working association with the Branch, and detailed plans for meeting these requirements as effectively as possible in an emergency are maintained and tested in regular exercises. Members of the staff represent the Meteorological Office at international meetings. Lectures are occasionally given to groups of Home Office Sector Scientists, Chief Warning Officers and members of the Royal Observer Corps who are equipped and trained to make simple meteorological observations in times of emergency.

Services for nuclear establishments

Certain Main Meteorological Offices supply meteorological information to nuclear establishments as part of precautionary arrangements to deal with

accidental release of radioactive or toxic materials from such establishments. These precautionary arrangements are tested without notice twice a year.

Climatological Services

The main function of the Branch is to provide information and advice about climate. The foundation of the service is a network of about 650 observing stations of various types in the United Kingdom (see Table IV on page 62) and the Office takes this opportunity to thank the many voluntary observers and authorities who contribute to this network for their excellent co-operation. The surface observations are summarized in the *Monthly Weather Report* (*MWR*) and its *Annual Summary* and in some non-routine publications. Since the beginning of the year computer methods have been employed for providing printer's copy for almost all the tables in the *MWR*. The use of the computer in the quality control of data has been further extended but some human control still has to be applied. In collaboration with the Systems Development Branch a study is being made of methods of improving the efficiency of computer quality-control of climatological data from Scotland and Northern Ireland by land-line transfer of data and corrections between Bracknell and Edinburgh and Belfast. In association with the Operational Instrumentation Branch work has continued on the development of a digital anemograph logger intended to eliminate the laborious hand analysis of wind records.

Developments in the application of climatology continued but not all demands could be met with the staff available. In order that work on projects of particular interest to it could proceed, therefore, the Department of the Environment agreed to fund two scientific posts in the Branch. These posts were filled early in the year. Discussions with officers of the Building Research Establishment suggested two important projects: first, the construction of maps of wind speeds exceeded for various percentages of the time over the United Kingdom and the development of a model to relate wind speeds measured in open country to those observed in towns and cities and over hills and, second, the preparation for major urban areas of England and Wales of memoranda describing the features of climate of particular relevance to the construction industry. Substantial progress has been made on both these tasks and in addition advice and information were provided for several scientists of the Building Research Establishment.

As part of a continuing study at the Building Research Establishment of wind damage to buildings, for some years the Branch has provided data and advice relating to occasions of strong wind which resulted in structural damage to buildings in the United Kingdom. Occasionally, when the damage has been of exceptional severity or when there has been some other feature of special interest, a detailed study of the weather situation has been carried out. Such an occasion was 26 June 1973 when tornadoes travelling along a line from Bedfordshire to the Wash caused damage at a number of places. A paper was published on this event.

The number of climatological inquiries handled at Bracknell, Edinburgh and Belfast increased by about 11 per cent over 1973 (Table XIII). As in

previous years these inquiries covered a wide range of interests and included many from legal and insurance firms about the weather at the time of occurrence of accidents and damage to property. A considerable number of inquiries were received from engineers, mainly about extreme wind speeds for the calculation of wind loadings on buildings and about temperatures and humidities for the design of heating, ventilating and air-conditioning installations. The wet weather during the second half of the year and the high winds in September gave rise to an unusually large number of requests for weather data from building contractors whose work had been delayed by inclement weather. Advice was given about the incidence of fog, cross-winds, frost and snow in connection with the planning and construction of new roads and by-passes in various parts of the British Isles and, in particular, a major investigation is being undertaken in collaboration with a firm of consulting engineers of the climatic factors along the possible routes of a new road over the Pennines between Manchester and Sheffield.

The explosion on 1 June 1974 which devastated the chemical plant at Flixborough, Humberside, and caused considerable loss of life led to a number of requests from interested authorities about the prevailing weather conditions. Research workers studying the blast from the explosion were supplied with estimates of winds and temperatures in the free air above Flixborough.

While most requests are for information relating to the United Kingdom, the Office also receives a considerable number of inquiries about the climate of other countries. Data to meet this requirement are usually collected by means of an international exchange of climatological information but some are obtained directly from a few Meteorological Office stations overseas. Examples of such inquiries received during the year are: from a manufacturer of adhesives who wished to assess the temperatures and humidities his product would have to withstand in various parts of the world; from a firm of consulting engineers who required an estimate of the maximum wind speed experienced during a tornado which caused the destruction of a power transmission line in Argentina in January 1974; from the Royal Society for the Protection of Birds who were interested in rainfall in the southern Sahara and the effects of the serious drought on migrant birds; and from a firm of consulting engineers who wanted information concerning intensities of rainfall in Iraq in connection with the design of a sewerage scheme.

The land surface climatologist is a member of several British Standards Institution committees concerned with the establishment of design standards for various structures. In connection with the design of lattice masts and towers, simultaneous occurrences of low temperatures and high humidities were studied in an attempt to define the likelihood of severe icing on such structures in different parts of the United Kingdom and an investigation of extreme temperatures was carried out in connection with design criteria for bridges. The above climatologist is also a member of a Working Group of the WMO Commission for Special Applications of Meteorology and Climatology dealing with *Guides* and *Technical Regulations*. This met in Geneva in June.

Climatological services for Scotland are provided by an office in Edinburgh. The number of inquiries dealt with by this office in 1974 exceeded that in 1973 by about 28 per cent, an important factor being the growth of the offshore oil industry. A report on the spell of very dry weather in recent years in east Scotland submitted to the Scottish Development Department showed that in

some places such a lack of rain is not likely to occur more often than once every 200 or more years. The Superintendent continued to serve on a working party of the Scottish Development Department dealing with storm sewerage and he also attended meetings of the Clean Air Council for Scotland as an Adviser. Plans have been prepared to move the office during 1975 to a new building situated about two miles to the west of the city centre. The building will be shared with the headquarters staff of the Forestry Commission.

Northern Ireland's climatological services are provided by an office in Belfast. In spite of the civilian unrest, all commitments have been met and the number of inquiries handled reached an all-time record. This reflects very highly on the staff concerned. In co-operation with the Northern Ireland Government the rain-recorder network has been extended and considerable progress made in devising a scheme for the analysis of the records by means of a hand-operated trace follower. This device automatically digitizes the trace for analysis by computer.

Preparation by the marine climatological section of the annual publications *Marine climatological summaries for the Atlantic Ocean east of 50° W and north of 20° N* was held up pending the re-writing of the necessary programs for the IBM 360/195 computer. Copies of magnetic tapes containing some 30 million observations from ships of various countries were acquired from the United States during the year; good progress has been made in writing and testing programs to extract wind, temperature and wave summaries for any desired sea area from these tapes. Charts showing the distribution of sea-ice at the end of each month were issued as usual. Work continued on checking ocean-current data and preparing them for computer quality-control. The ocean-current and, where applicable, the sea-ice sections were revised for five volumes of the Admiralty *Pilots*. Revision of the sea-ice sections for Volumes II and III of the *Arctic Pilot* was of particular interest in that the results of a major investigation were incorporated. This investigation, completed during the year, was to prepare new normals and frequency distributions of sea-ice in the Arctic from the data of a recent eight-year period. During this period surveillance of the ice edge was more comprehensive than previously because of the availability of satellite pictures covering areas where few, if any, surface observations were made. Though the work was based on a relatively short period of data the extreme position of the ice edge in many areas lay beyond those previously accepted.

Work for the *Marine Observer* continued with articles on sea-ice and notes on phenomena described by mariners in the 'Marine Observer's Log'; in addition to these routine items, an article was written on unusual waves encountered off south-east Africa.

Many inquiries relating to marine climatology, ocean currents and sea-ice were dealt with. A high proportion of these related to the exploration and exploitation of oil resources under the sea, mostly the North Sea and areas north of Scotland but occasionally in more distant parts of the world. The following illustrate the variety of other purposes for which marine climatological data were supplied: to appraise possible harbour sites in Caithness; to plan an expedition to Baffin Land where ice in fiords was expected to hinder transport; to plan a hovercraft service; to design a yacht for a specific race.

The marine climatologist became increasingly involved in matters concerning the offshore oil industry. He was one of the United Kingdom delegates at a

meeting, held in London in April, of a Working Group on Environmental Matters affecting Offshore Installations which had been set up by the European States Conference on Safety and Pollution held the previous year. Representatives from eight European countries attended and examined the availability, exchange, processing and presentation of meteorological, oceanographic and sea-bed data for the offshore areas. It set up a sub-group consisting of members from France, Norway and the United Kingdom to examine the environmental data in order to harmonize environmental standards to be used in the design of offshore installations over the whole of the west European continental shelf. As Office representative the marine climatologist attended seven meetings of the Offshore Installations Technical Advisory Committee of the Department of Energy. *Guidance on the design and construction of offshore installations*, prepared by this Committee and published by Her Majesty's Stationery Office in March, incorporates much meteorological information bearing on the subject. The marine climatologist also represented the Office on a new British Standards Institution committee which is to draft a code of practice on the design of fixed offshore platforms and which met three times. He continued as a member of the Working Group on Marine Climatology of the Commission for Marine Meteorology (CMM) of WMO and as CMM rapporteur on the meteorological aspects of icing on ships. In the latter capacity he completed a review paper on the subject which is to be published shortly by WMO and he also attended, as WMO representative, a meeting in London of the Inter-governmental Maritime Consultative Organization Sub-committee on Safety of Fishing Vessels.

Hydrometeorology

The regular collection, processing and preservation of rainfall data from nearly 7000 stations and evaporation data from some 60 stations in the United Kingdom and Northern Ireland continue to be routine functions of the hydrometeorological section. The Edinburgh office administers and inspects stations in Scotland, handles their data and deals with local inquiries; the Belfast office has similar responsibilities for Northern Ireland. Most of the data are collected from voluntary co-operating stations maintained by the new Regional Water Authorities which were set up on 1 April 1974 when the water industry in England and Wales was re-organized by the Water Act 1973. Private individuals continue to supply much useful data. Rainfall data are published in the *Monthly Weather Report* and in *British Rainfall* and occasionally in branch memoranda. During the year *British Rainfall* for 1967 was published.

Hydrometeorological inquiries covering a wide field were received from a number of commercial concerns, the legal profession, universities, water authorities, private individuals and others; the number of inquiries showed an increase of 45 per cent on the previous year. As in other years the most frequent inquiries concerned legal and insurance matters (including insurance against rainfall for fêtes and other events), the building industry and water supply and disposal. There were many inquiries from farmers, water supply undertakings, etc. after the dry spring (March–May) and from the building and construction industry after the heavy rainfall of early autumn. Inquiries concerning the frequencies of rainfall amounts in specified durations for various

locations in the United Kingdom have increased apace. Information (based on the results of the Flood Studies investigations in the Office in recent years) can be supplied for the probability of occurrence of specific rainfall amounts (in specified durations from 1 minute to 25 days) which will be equalled or exceeded as often as twice a year to as infrequently as once in 100 years. Values can be provided at very short notice for any point or area within the United Kingdom. Similar analyses were carried out for locations in the Middle East. Computer programs have been developed to facilitate the answering of inquiries, for example the display of hourly rainfall amounts and the frequency of rainfall exceeding specified values at a particular station. A visual display unit of the computer installation has been used with increasing frequency and promises to be a valuable tool in dealing quickly with inquiries.

Perhaps as a result of the major reorganization of the water supply and disposal industry by the Water Act 1973, major hydrological inquiries have been fewer than in previous years. For the Thames Water Authority, estimations of daily areal rainfall and monthly potential evaporation were completed for a number of subdivisions of two major aquifers for the years 1920–71 and, for the same Authority, point values of average annual rainfall and potential evaporation were produced for each node of 1-km square meshes, covering the Wey, Mole and Loddon valleys. Estimations of monthly areal rainfall, potential and actual evaporation over a large part of the Great Ouse basin were supplied to the Essex River Authority for the years 1932–35 and 1970–73. A start was made on producing monthly areal rainfall values back to the 19th century (in one case back to 1850) for five major catchment areas, viz. the Thames at Teddington, the Severn at Bewdley, the Usk at Chain Bridge, the Ely Ouse at Denver and the Wye at Cadora; long-period evaporation values were also asked for by the Central Water Planning Unit. Monthly estimates of evaporation from Lough Neagh, allowing for heat storage in the Lough, were supplied to the Freshwater Biological Investigation Unit (Northern Ireland).

Areal rainfall values for the Surface Water Survey are calculated as a routine for more than 500 catchment areas. The data are to be stored in the Water Data Unit's archives and relevant values are provided as a routine to many water authorities. The bulletin *Estimated soil moisture deficit and potential evapotranspiration over Great Britain* was issued at frequent intervals. Improved computer programming has facilitated issue at short notice and this was particularly useful in 1974, because of dry spring weather and wet weather later in the year.

Final amendments were made to the contribution of the Office to the *U.K. Flood Studies Report* which is to be published by the Natural Environment Research Council early in 1975. This major 5-volume report will contain the meteorological studies in Volume 2 and the maps of rainfall parameters in Volume 5. The other main contributors to the *Flood Studies Report* are the Institute of Hydrology and the Hydraulics Research Station, Wallingford.

Computer programs have been developed so that many of the applications of the results obtained in the Flood Studies Project can now be readily applied to meet user requirements. In particular, rainfall statistics have been produced for over 400 towns and cities in the United Kingdom.

Investigations are continuing into the refinement of relationships between intensity and frequency of occurrence of short-duration rainfall and also into storm profiles. A special study is also being made of relationships between

rainfall amounts, durations and frequency of occurrence by using computer mapping techniques, radar data, satellite data, etc.

Trials have been carried out of the Transport and Road Research Laboratory's model for storm-sewer design based on their *Road Note 35* using storm profiles as presented in the *Flood Studies Report* Vol. 2. These trials have led to a method of improving the input of rainfall information in models for storm-sewer design.

Some further work has been done to improve the computer systems for the quality control of rainfall and also the comprehensive areal rainfall programs (CARP). Computer-produced maps of daily and monthly rainfall totals were produced for several inquirers, including the Royal Radar Establishment, Malvern and Imperial College, University of London.

Work continues on two methods of obtaining detailed rainfall information over very short time intervals from rain recorders in a form which can be used in computers, viz. the use of magnetic-tape event recorders (MTER) and the precision encoding and pattern recognition (PEPR) equipment at the Nuclear Physics Laboratory, Oxford; progress has been slower than expected, partly due to staffing problems. (See also page 50.)

The program to compute annual average rainfall for the period 1941–70 for several thousand rainfall stations, including making estimates for many rainfall stations with quite short records, has virtually been completed despite set-backs due to uncertain quality of some of the archived records.

A good deal of investigational work has been done with a view to improving the soil-moisture advisory services. Special data banks of the land use of Great Britain and of climatological data have been created in the computer and programs have been written to select relevant data from the operational data banks and to process these several sets of data to calculate soil moisture deficits. The work is still experimental but the results are promising. A useful set of end-of-month soil moisture deficits has been built up for a number of stations from 1941 and work has started on a climatology of soil moisture deficit. The frequency distribution of end-of-month soil moisture deficit was investigated and a map was prepared showing the average annual maximum soil moisture deficit at each node of a 10-km square mesh grid over England and Wales. The map was extended over Scotland but values, particularly in highland areas, are uncertain in view of the scarcity of data on which to base the map.

Records of rainfall and estimates of potential evaporation representative of Kew since 1698 were used in an analysis of rainfall deficiencies, ranking individual droughts in terms of their impact on water management and agriculture. This analysis showed up the rarity of the combination of low rainfall and high potential evaporation in the inclusive period December 1971 to November 1973.

Work has been done on expressing the severity of rainfall deficiencies and excesses in terms of return period. This work will enable past deficiencies and excesses of rainfall to be ranked, as required by water management bodies, and will form the basis of an operational rainfall-monitoring service. A preliminary deficiency-ranking system was brought into use.

Some work has been carried out on snow over the United Kingdom, and attention is being focused on rates of snowfall, water equivalent of lying snow and on the persistence of lying snow.

The Dee Weather Radar Project continued through the year. It has now

been demonstrated that quantitative areal rainfall can be derived by utilizing radar measurements on a space scale and with an accuracy appropriate to hydrological requirements. Progress has been made toward the objective of developing a system incorporating radar to measure rainfall in real time, primarily for hydrological purposes and use in river regulation. In April the water industry was reorganized and the participation in the Project by the former Water Resources Board was continued by the Water Research Centre, the Central Water Planning Unit and the Water Data Unit. The former Dee and Clwyd River Authority became part of the Welsh National Water Development Authority and continued the co-operation. Plessey Radar Limited continued to be associated with the investigations. At the end of 1973 the radar was modified to operate with a beam width of 1° instead of the earlier 2°, this being accomplished by changing the wavelength from 10 cm (S-band) to 5·6 cm (C-band). This change resulted in a significant reduction in the amount of echo returned from the terrain and enabled rainfall measurements to be made over all of the 360° field of view of the radar, an improvement on the previous system. In addition the narrower beam width in the vertical reduced the number of occasions when sleet* was present within the beam at a given range; on such occasions accuracy of the assessments of precipitation is much reduced. The analysis confirmed the results from previous years that, in the absence of the melting layer in the radar beam, the radar assessments of the rain falling on to sub-catchments are in error typically by 15–20 per cent, the error increasing with distance from the rain-gauge used to calibrate the radar system. Accuracy can be improved by increasing the number of calibrating locations. An objective method for correcting for at least part of the increased error which arises when the melting layer is within the beam was developed; typically errors over sub-catchments are then 25–30 per cent. A computer-based method of predicting the distribution and intensity of the echo received from the terrain for any potential radar site was developed. The method, which uses a digitized contour map as the main input, will be a very useful aid in deciding on the suitability of possible sites for future weather radars. A study of the relationship between rainfall amounts over sub-catchments of the River Dee and over the catchment as a whole was completed. This showed that in almost all weather types the rainfall over small areas of the River Dee, which are of most interest to hydrologists, can be estimated quite accurately from the larger-scale rainfall.

In the latter part of the year a PDP 11/40 computer, purchased by the Water Resources Board, was added to the radar system at Llandegla and, using software developed for the Meteorological Office by a team at the Royal Radar Establishment, quantitative rainfall measurements were available in real time. Work is beginning to determine whether the accuracy of real-time measurements is comparable to that obtained from previous work carried out *ex post facto* at Bracknell. The radar system is now a prototype of a system which could be developed to provide real-time data of precipitation to a variety of users, via telephone lines.

The team of seven led by the Principal Scientific Officer attached to the Institute of Hydrology, Wallingford has continued its work on the Thetford Project. This is a multi-disciplinary hydrological study of an extensive area

* Rain or drizzle and snow.

of pine forest and much of the year has been devoted to analysis of the micrometeorological data collected as part of the Project. This analysis has shown that the average daily value of the biologically controlled resistance to water flow from the pine trees to the atmosphere does not vary significantly with the season of the year or from year to year. This result may permit the use of a very simple model of the surface resistance, related to the time of day, with the Monteith–Penman equation to estimate the annual transpiration from the forest. Analysis of occasions when the forest has been completely wetted by precipitation has shown that on average the humidity deficit has the same value whatever the value of the net radiation. This means that when the net radiation is below a certain level the energy used to evaporate intercepted precipitation exceeds the flux of energy from net radiation, implying wide-scale advection of energy on these occasions. During the summer the fluxes derived from gradients of temperature and humidity measured by static sensors mounted at seven levels were compared with those values obtained using a system which mechanically interchanges a pair of psychrometers between two levels to remove systematic errors from the measured gradients. In return for greater mechanical complexity and poorer reliability this psychrometer-interchange system greatly improved the accuracy of the measured gradients. Also the Fluxatron—a simple eddy-correlation system for measuring sensible heat flux, developed by a division of the Commonwealth Scientific and Industrial Research Organization in Australia—was tested over the forest and found to perform encouragingly well.

An automatic system for recording the components of precipitation in a forest, i.e. through-fall, stem-flow and gross precipitation, has been running for much of the year, so that the interception of precipitation by the forest canopy can be studied. Investigations of the biological and soil-moisture aspects of the hydrological cycle of the forest have also been carried out.

In the week following the International Union of Forestry Research Organizations Conference held on 16–20 September, at which members of the Thetford Project presented results, a Workshop meeting was held at Wallingford to discuss a joint publication to compare the results from four micrometeorological investigations over forests, located in the U.S.A., Canada, Scotland and England. A unified procedure for analysis and presentation of results was agreed upon.

The Office continued its contribution to international hydrometeorology through co-operation with the World Meteorological Organization and Unesco and Mr R. Murray was a member of the U.K. delegation at the joint WMO/Unesco End-of-decade Conference on Hydrology at Paris in September. The Office was represented on the British National Committee of the International Hydrological Decade and also on Sir Norman Rowntree's working party set up by the Natural Environment Research Council to report on Hydrology and Hydrogeology in the United Kingdom.

Services for Agriculture

The number of staff employed in Agricultural Meteorology showed no significant change during 1974, but following a review of the services to agriculture provided at Cambridge the second post there was upgraded to Scientific

Officer/Higher Scientific Officer. This post was eventually filled in September. With increasing emphasis in the Agricultural Development and Advisory Service (ADAS) on Research and Development the importance of meteorological advice during the planning of experiments has been recognized and meteorological staff take part in the discussions of the appropriate committees. The removal in 1973, due to pressure on accommodation, of the Meteorological Office from the Yorks. and Lancs. Regional Office of ADAS at Leeds to Harrogate has made liaison with regional advisers more difficult than in the past but weekly visits are made to Leeds. Co-operative work and discussions have continued with many of the Agricultural Research Council Institutes, the Central Veterinary Laboratory, the Plant Pathology Laboratory, Experimental Husbandry Farms and Experimental Horticultural Stations. Two members of headquarters staff are associated with the Joint ADAS/ARC Committee on Grassland Manuring, one on the main committee and one on the Working Party. A comprehensive series of nitrogen manuring experiments on 28 sites in England, Wales and Scotland has just been completed. In order to interpret the results from these experiments climatic aspects must be fully investigated. The Bristol office is closely involved in a project in the West Midlands organized by the Permanent Pasture Group at the Grassland Research Institute, Hurley.

The definition of agroclimatologically homogeneous areas is almost complete after discussions at ADAS regional level. An average height for each area is being calculated using existing computer programs of the Agriculture and Hydrometeorology Branch. A high degree of agricultural as well as climatological homogeneity has been obtained in these areas, which may facilitate the direct application of agricultural statistics to agrometeorological research. This has not previously been possible. Departures from average of relevant climatic variables will be issued for the new areas on the weekly weather reports distributed to ADAS and averages of potential transpiration, previously published for administrative counties, will be produced for the areas.

In 1974 an operational barley-mildew warning scheme was set up in England and Wales. It has been estimated that this disease cost barley growers in England and Wales about £37 million in lost yields in 1973. Daily meteorological observations received at Bracknell from synoptic stations were used to obtain indices which identified meteorological conditions favourable for the rapid spread of the disease. These indices were passed to regional plant pathologists in ADAS who, on the basis of this and other relevant information, issued advice to their region on the best time for a single controlling spray to be applied. Since the meteorological data used are stored in the synoptic data bank of the computer, the possibility of automatic extraction and processing of the data on a routine basis has been investigated. This will obviate the need for lengthy hand-extraction from teleprinter messages.

Notification of Beaumont periods in connection with potato-blight warnings has continued, but warning criteria based on the number of hours with relative humidity above 90 per cent have been further investigated. Preliminary results are promising and a revised warning scheme may be introduced in 1975. The possibility of computer handling of incoming messages from synoptic stations has made such a scheme feasible.

With outbreaks of swine vesicular disease (which has clinical symptoms similar to foot-and-mouth disease) continuing throughout the year, staff in the

Agricultural Meteorology section have frequently been on stand-by for possible deployment to an epidemiological control centre in the event of confirmation of foot-and-mouth disease. During the year foot-and-mouth disease has been confirmed in Brittany, Jersey, Belgium and West Germany (near Frankfurt) and analyses have shown that there was a small risk of wind-borne spread to the United Kingdom during the French and Belgian outbreaks.

A wide variety of investigations into relations between climate and agriculture and horticulture have been carried out. With the high cost of importing cereals and protein for animal feedstuffs there have been requests for information on climatically suitable areas for the growth of maize, oil-seed rape and legumes. Additionally there has been interest in the commercial introduction of autumn-sown onions and navy beans (used for baked beans). Unfortunately the climatic limitations to the successful growth of these two crops have not been clearly defined and considerable further research in this is needed. Considerable emphasis has been given to the production of high-quality conserved forage for winter feeding of animals. This requires timely cutting of the crop in relation to its digestibility and nutrient content. Studies of 'pickup' days for wilted silage or hay have shown the low probabilities of obtaining suitable weather conditions for field-dried hay in many parts of the country. The analyses have been extended to include a consideration of the humidity of the air as well as the absence of precipitation. Hours suitable for combine harvesting and crop spraying have been investigated by using computer programs. Glasshouse heating requirements have also been calculated from wind and temperature data.

The dates of return to field capacity, excess winter rain and irrigation need for grassland have been calculated for the main agricultural areas in Scotland.

Experimental work has included investigations of conditions of bulk onion storage, potato storage, maize seed-bed temperatures under various treatments such as applications of slurry or bitumen mulch, temperatures in calf houses, and the microclimate around a pear tree.

Mr R. Murray and Mr C. V. Smith were the U.K. delegates to the sixth session of the WMO Commission for Agricultural Meteorology in Washington in October 1974. For this meeting a National Progress Report on Agrometeorology in the United Kingdom was prepared and this incorporated information from U.K. institutions active in the field. The report of the Meteorological Office rapporteur on mulches, appointed by this Commission after its fifth session, was completed and is to be published as a WMO *Technical Note*.

Observational Requirements and Practices

The Branch, of which the Marine Division under the Marine Superintendent is a part, has overall responsibility for organizing the provision and maintaining the quality of regular meteorological observations made over land, at sea and in the upper atmosphere in sufficient numbers and with a distribution in space and time appropriate to meet national and international requirements. It specifies how the sensors of meteorological instruments and observing systems shall be exposed, and details the observational techniques to be

employed. It arranges for observing stations to be inspected regularly to ensure the maintenance of approved standards of site, instrumentation and observational procedures. Field trials are organized of new or modified instruments or observing systems to determine their suitability for operational work, optimum procedures for their routine use, and the effect of their introduction on the accuracy and comparability of the basic observational data.

The Branch works in close liaison with the Operational Instrumentation Branch on the one hand, and with the forecasting, climatological and hydrological branches on the other. It provides the chairman and secretary of internal working groups concerned with reviewing the U.K. observational networks, and with planning a network of operational weather radars. In the international field, the Assistant Director (Observational Practices) serves on the WMO Working Group on the Global Observing System (GOS), whilst senior branch members serve on working groups concerned with radiation measurement and with the requirements, accuracy and quality assurance of observational data.

Observatories

The Observatories at Kew and Lerwick, and the Meteorological Office section at Eskdalemuir, have continued to provide facilities for testing new instruments and techniques as well as being important stations in the observing network. The staff at Kew Observatory has been greatly reduced, following the move of the Regional Radiation Centre and the routine radiation calibration work to Bracknell, but a full routine of observational work is being continued.

The comparison at Kew between the recording gravimetric rain-gauge and the standard rain-gauge has continued and the analysed results have been reported in a paper to be published in the *Meteorological Magazine*. A paper has also been prepared for publication on the comparison between the air temperatures recorded in the large thermometer screen and those recorded with the aspirated psychrometer.

The external fabric of Kew Observatory has now been renovated and redecorated and this historic building is once again attractive to look at.

Lerwick is a WMO Regional Sampling Station, and the staff have continued to assist in the operation of a second chemical sampling station at a remote site some 35 miles ($\approx$ 56 km) from the Observatory. The main purpose of the second set of measurements is to assess whether the Observatory is affected by any local sources of pollution now that there is increasing commercial activity in the nearby town, associated with the provision of support facilities in the Shetlands following the North Sea oil discoveries. Observations from this remote site have now been obtained for nearly two years but it has not yet been possible to identify with certainty any systematic difference of atmospheric pollution between the sites.

Surface observations

Several different types of surface observations are made to meet various requirements. Meteorological observations made at fixed times from a network of stations are required without delay for use in weather analysis and forecasting. In the United Kingdom 76 synoptic observing stations report every hour of the day (24 hours) throughout the year; a further 47 stations report every 3 hours. In addition, 142 stations report at various times each day of the year. Of this

total of 265 stations, 90 are manned by full-time Meteorological Office staff, being located mainly at civil and military airfields, 73 by coastguards and lighthouse keepers, and 70 by staff of other official and public bodies. The remaining 32 stations are maintained by private individuals, who fill a most valuable role by providing observations in areas where facilities for the above types of station are sparse or non-existent.

Meteorological observations are also required to meet a variety of needs other than those of weather forecasting, e.g. for agricultural, town planning, and industrial purposes. These observations become part of the permanent store of weather information (our weather 'memory') and are usually classified as 'climatological'. Most of the stations manned by Meteorological Office staff and some of the other stations which make observations used in weather forecasting also make monthly returns of climatological data, many of them for a number of observing hours each day. Additionally, over 500 co-operating stations, mostly manned by voluntary observers, make an observation at 09 GMT each day, with a small number making reports at other hours also. Courses for voluntary observers are held at the Meteorological Office College; there are, however, only a limited number of places available each year and these courses are invariably over-subscribed.

In addition to stations making comprehensive observations of the weather, it is necessary to have a very much larger number of stations measuring rainfall only, in order to provide adequate data for detailed studies of the distribution of rainfall. The information thus acquired is of great value for use in connection with such purposes as water supply and agriculture. The rainfall observing network consists of nearly 7000 stations, a few of which also measure evaporation. Nearly all of these stations are voluntary co-operating stations, maintained by various authorities (now mainly the new Water Authorities) and by private individuals. During the year a major reorganization of water authorities within England and Wales took place, when the functions performed by a large number of water supply undertakings and other authorities were taken over by 9 newly formed Regional Water Authorities in England and a Welsh National Water Development Authority. The station records of several thousand rainfall stations were affected by this change-over and have been completely reorganized in consequence.

Reports in plain language are received from 16 town offices of the Automobile Association and the Royal Automobile Club, 16 Police or Fire Service stations and 51 road-maintenance depots located alongside motorways.

The organization of radiation observations in the United Kingdom and at certain other stations overseas is specifically mentioned as one of the functions of the Meteorological Office and the Observational Requirements and Practices Branch is responsible for this aspect of the work. Measurements of solar and terrestrial radiation have long been made at Kew Observatory. In the early 1950s systematic measurements were also begun at a number of other Meteorological Office stations and the International Geophysical Year (1957–58) was a stimulus to this work. The network has been extended somewhat since then and at present radiation observations are made at eight Meteorological Office stations in the United Kingdom, on four ocean weather ships and at two Meteorological Office stations overseas. Systematic solar radiation measurements are made also by various other bodies for their own purposes (Agricultural Research Institute and stations, government research stations,

university departments) and copies of these data are collected by the Meteorological Office whenever possible.

To obtain reliable radiation measurements is not easy because it is necessary to inspect and calibrate regularly both the measuring instruments themselves and the recording systems, and to ensure that the proper procedures are followed. The standard instruments against which all the others are calibrated are a set of Ångström pyrheliometers. These were formerly held at Kew Observatory, which was designated a Regional Radiation Centre by WMO but, as announced in the 1973 *Annual Report*, this work has now been transferred to the Meteorological Office experimental site at Beaufort Park, near Bracknell.

Intermediate working standard instruments are calibrated directly with the Ångström pyrheliometer on clear days by using the sun as a source of radiation; these working standards can then be used to calibrate routine instruments using an artificial source of radiation indoors. The routine calibration of radiation instruments is now, however, undertaken by the Operational Instrumentation Branch. Newly recalibrated instruments are sent regularly to all Meteorological Office stations measuring radiation and the instruments they replace are returned for recalibration. In this way the effects of faulty instruments or slow drifts in calibration are minimized and corrected as far as possible.

The Meteorological Office Ångström pyrheliometers are compared against other international standard instruments at the International Pyrheliometer Comparisons organized by WMO at regular intervals (about every five years).

The radiation instruments used at non-Meteorological Office stations are also calibrated on request in the interests of obtaining homogeneous and reliable data.

The radiation data are stored in a form suitable for use on the computer (most of them are on magnetic tape) and suitable programs for providing printed data in a variety of formats have been written. There has been a remarkable upsurge in the use of radiation data in the last two years, mainly as a result of the energy crisis, and the Branch has done its best, within the limits of its staff resources, to meet requests for basic data and analyses from a wide variety of bodies (government departments, universities and private individuals). In particular a senior member of the Branch is serving on a Panel set up by the International Solar Energy Society with the aid of a grant from the Wolfson Foundation, which is to prepare a report on the possibilities of solar energy utilization in the United Kingdom.

An investigation into the secular changes in the transmission of the atmosphere as shown by the routine radiation measurements has also been restarted.

Upper-air observations

The normal programme of upper-air observations was attempted at the eight stations in the United Kingdom, on four ocean weather ships and at the five stations overseas. At the upper-air station at Long Kesh, however, some observations were missed or curtailed because of the continued unrest in Northern Ireland. At Episkopi, in Cyprus, only three observations were missed despite staffing difficulties during the troubles on the island.

Advice and assistance on radiosonde matters continued to be given to other

branches of the Office and to outside bodies. Close collaboration was maintained with the branch responsible for the establishment of upper-air stations in support of the U.K. contribution to World Weather Watch. One of these stations, located in the Anglo-French Condominium of the New Hebrides, was inspected by a member of the Observational Requirements and Practices Branch. Close liaison was also maintained with the Operational Instrumentation Branch regarding the development of the Mk 3 radiosonde.

Thunderstorm location and surveillance

The thunderstorm location networks comprising four U.K. and three Mediterranean cathode-ray direction finding (CRDF) stations maintained a full programme of observations throughout the year despite some loss of bearings from Northern Ireland and a very small loss from Cyprus at the height of the troubles there. The U.K. network operated during 10-minute periods for 22 hours daily whilst the combined U.K. and Mediterranean stations operated together during further 10-minute periods for 16 hours daily.

During the year an appraisal of the system was started which included a comparison between positions determined by the CRDF network and thunderstorms reported by the stations of the meteorological visual observing network in Europe and the Mediterranean basin. Out of samples taken every three hours in full daylight there were 3088 positions that could be reasonably matched with meteorological reports. For each match the distance between the position and the report was found. Such distances arise mainly from errors in positions obtained, with a small contribution from the visual reports. The distances were grouped separately for different geographical areas and then for each area a limit was found within which 50 per cent of all distances lay. Figure 2 gives isopleths which show the geographical distribution of the 50 per cent limits and which can be taken as an estimate of position errors during the daylight hours of March to August 1974. These errors are smallest over the United Kingdom, where direction-finding stations are closely grouped, and a zone of minimum error extends south-eastwards from the British Isles to beyond Malta. The extreme errors in the north-east could be reduced by including in the network a direction-finding station to the far north of the United Kingdom.

Runway visual range

Routine check calibrations of the human observer system used to assess runway visual range have been carried out, at six-monthly intervals at 33 civil airports and 36 RAF stations, including five in West Germany and one in Cyprus. The remaining two RAF systems to be installed are expected to be completed in early 1975. Automatic instrumented systems are in operational use at the major airports (London/Heathrow, London/Gatwick, Manchester and Glasgow); the human observer system has been discontinued at Heathrow and Glasgow but it is still kept in calibration at the other two airports.

Marine Division

The numerical strength of the U.K. voluntary observing fleet has remained almost unchanged throughout the year. The six Port Meteorological Officers

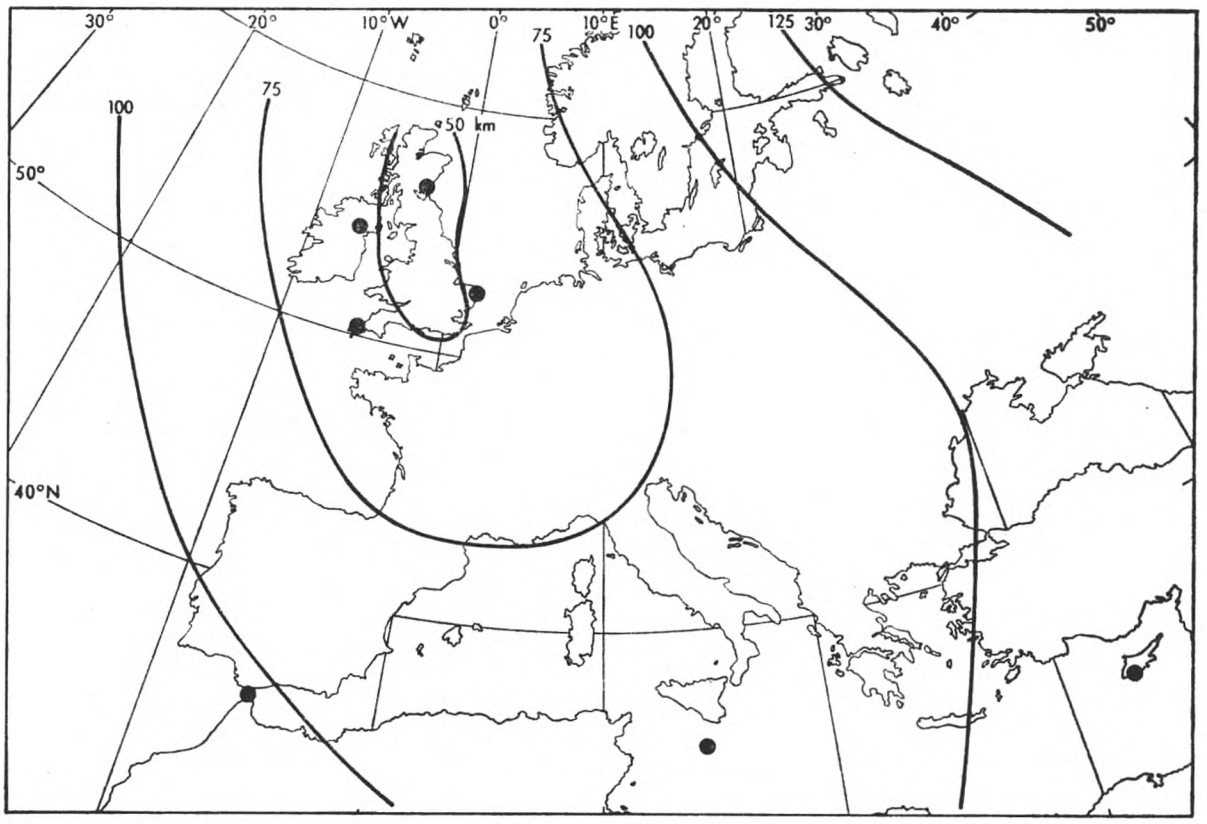


FIGURE 2—ERRORS OF THUNDERSTORM POSITION REPORTS

Estimate of the variation over the service area of the error of position reports exceeded on half of all occasions

● direction-finding stations

at the main ports, on whom most of the effort of maintaining and building up the strength of the voluntary observing fleet rests, have found that frequently the number of new recruitments is equalled by the number of withdrawals as a consequence of ships being sold or laid up for long periods. The number of observations received has, nevertheless, increased since the fast container and bulk-carrier-type vessels spend more time at sea than their predecessors and are able, therefore, to make a greater number of observations. The Port Meteorological Officers at Glasgow, Liverpool, Hull, Cardiff, Southampton and London have continued their liaison work between the Meteorological Office and the various shipping interests, which is of mutual benefit. Apart from the few special-purpose ocean weather ships, meteorological work at sea in British merchant ships has always been carried out on a voluntary basis and it is gratifying to report that the standard of these observations has been, in general, well maintained throughout the year; where a deterioration has been noticed, and there have been a few cases, it has almost invariably been found in ships which are now sailing with smaller crews than previously. This unfortunately may become more serious in the future as means are being continuously sought to reduce the number of qualified and experienced personnel in modern ships and the practice of changing officers at four-monthly intervals accentuates the problem. The practice of appointing Port Meteorological Officers who are themselves master mariners with considerable experience as voluntary weather observers contributes significantly to the scheme and proves to be extremely helpful to the shipping industry.

The shipmasters, principal observing officers and radio officers who have been responsible for sending in the 100 best meteorological logbooks during the year were, as is customary, nominated for 'Excellent' awards. Barographs were presented to four shipmasters for their long and zealous meteorological work at sea. Awards were also made to Masters and officers of vessels on the short sea trades for their contribution in making sea-temperature observations and to trawler skippers and radio officers who had the best records in making and sending non-instrumental observations from the fishing regions.

The policy of installing distant-reading meteorological equipment in a number of ships under construction, in order to ease the work-load of observing officers, continues to receive the whole-hearted support and co-operation of shipowners.

Once again the Marine Division is indebted to many Port Meteorological Officers in the Commonwealth for holding a small stock of instruments for the replacement of defective instruments on U.K. voluntary observing ships, calling at their ports while being away from the United Kingdom on protracted voyages, and for withdrawing instruments from such ships as may have been sold during their voyage. As these sales become more frequent, the value of such timely intervention of Port Meteorological Officers overseas to prevent the loss of instruments is enhanced since notice is not always given of such transactions.

The present four British ocean weather ships, ex 'Castle' class frigates built for the Royal Navy in 1944, have now been in service as weather ships for about 15 years. In spite of increasing difficulty in manning at both officer and rating level, these ships continue to give reasonably satisfactory service, though as a natural consequence of their age, repair and maintenance costs continue to mount. These ships manned Stations 'India' and 'Juliett' and co-operated with the Netherlands and Norway in occupying Station 'Alfa' part time until 30 June after which the Station was no longer manned.

The rules and regulations governing the equipment and operation of the weather ships are administered by the International Civil Aviation Organization supported by the World Meteorological Organization. All ships make hourly surface and six-hourly upper-air observations (for heights reached in upper-air ascents see Table V of statistics). The following additional observations were regularly made by British weather ships: solar radiation, sea temperature and salinity down to considerable depths, magnetic variation and surface sea-water sampling. The biological sampling programme for the Institute for Marine Environmental Research was continued throughout the year, the Longhurst/Hardy plankton recorder being used to determine the vertical distribution of plankton in the upper 500 metres of the ocean at Station 'India' and, for this duty, a marine biologist from the Institute made several voyages to the station. In association with this investigation into the plankton hauls, water samples for phytoplankton analysis were taken and extra net hauls for analysis of toxic residues in the plankton were made. In the latter part of the year, the Marine Aerosol Sampling Programme commenced. This is a project undertaken in co-operation with the Royal Navy (National Gas Turbine Establishment, Naval Marine Wing) to obtain and analyse air samples for salt-particle content.

Communication and navigational facilities were available from all British weather ships for transatlantic aircraft and air–sea rescue equipment was kept

in a constant state of readiness. Search and rescue exercises were frequently carried out and a Nimrod aircraft of the Royal Air Force sometimes participated.

The Marine Division was responsible for the survey and charter negotiations for the acquisition of two small vessels, which formed part of the U.K. marine contribution throughout the GARP Atlantic Tropical Experiment from 15 June to 30 September 1974.

The number of marine inquiries, most of them from solicitors, shipping companies, universities and industrial firms, has greatly increased over previous years. The *Marine Observer* was published quarterly as hitherto.

The Marine Division continued to co-operate closely with the Central Forecasting Office in the weather routeing of ships in the North Atlantic and North Pacific Oceans. The administration of the Ship Routeing Service was transferred to the Marine Division on 1 October 1974.

Operational Instrumentation

The Branch continues to develop a wide range of equipment to meet the diverse needs of user branches. This requires first an appropriate choice of sensors and observational techniques, which is arrived at in consultation with the Observational Requirements and Practices Branch, and secondly the development of systems to capture the data at source and telemeter this information, without loss of quality, over distances ranging from tens of metres to tens of kilometres. At the receiving end of the telemetry link, there is generally a need for single or multiple displays of data which may be electronically processed to some extent. Alternatively, or in addition, there may be a need for the data to be recorded in the form of continuous analogue traces or to be incrementally logged on magnetic tape for subsequent processing by computer.

Far from introducing such automatic instrumentation to enhance the present observational networks, it is rapidly becoming a question of whether equipment can be developed and evaluated fast enough to fill the gaps created by the growing shortage or disappearance of human observers, e.g. on lighthouses, light-vessels and ships of opportunity. This is not to suggest that such equipment has reached a state of development where it can operate unattended; rather that it is becoming easier and more economic to obtain a round-the-clock coverage of observations by using automatic systems which receive occasional attention from caretakers and servicing staff. It is unlikely that these new systems will provide all the information in the same detail as in a conventional observation but meteorologists in many countries are rapidly adapting to the use of these new sources of data.

Two activities are singled out for special mention this year: the placing of the major contracts for the computerized ground stations and central automated calibration plant for the Mk 3 radiosonde system; and the growing importance of the Office's programme of development of automatic ocean data acquisition systems which owes much to the co-operation of other organizations.

By the end of the year, the first batch of the new Mk 3 radiosondes had been delivered and were undergoing stringent acceptance testing. The contracts for the ground-station equipment and calibration plant were placed in April, and since then there has been constant and detailed technical liaison

with the manufacturers and with the Procurement Executive of the Ministry of Defence on the hardware and software specifications. Preparations are going forward for the installation of the calibration plant at Eastern Road, Bracknell, and the first of the ground stations at Beaufort Park, next summer.

The low-capability buoy OBOE I was moored in the Thames Estuary from February until September when it capsized in Force 10 winds. In spite of this, the electronics and radio transmitter were undamaged after immersion for over a month. The capacity of the batteries was increased to enable the system to be operated for 3 months, and an experimental wind direction sensor was added, based on a digital compass and wind vane arrangement. The shore station was placed at the Port of London Authority's marine communications station at Warden Point. Construction of the operational version OBOE THAMES is now nearing completion, and this will provide routine data every three hours (or on demand) for the London Weather Centre later next year. The data-acquisition system to be incorporated is the prototype of a general-purpose system which will find applications in many other fields.

Co-operative projects: national and international

Senior officers of the Branch were much involved with two projects sponsored by the European COST (Co-operation in Science and Technology) scheme. One of them is chairman of the nine-nation Project 72 sub-group on Automatic Weather Stations which held two further meetings at Shinfield Park and produced a survey of the role these devices are likely to play in European networks. Another is a member of the corresponding six-nation Project 72 sub-group on Radiosondes which held two meetings at Trappes, near Paris, to plan laboratory and field comparisons of radiosondes and radio-wind devices used by European services. Information was also supplied to the Project 72 Rapporteur who produced a report on the present situation in respect of radiosonde balloons in Europe. A third officer of the Branch is a member of the Project 72 sub-committee which co-ordinates these activities on the development and standardization of meteorological instruments.

Under the companion Project 43 which is concerned with the creation of a European network of meteorological/oceanographic data buoys, plans are now taking shape for setting up five small pilot networks including three which are of particular interest to the United Kingdom: North Sea/Baltic, Biscay and Faeroes/Shetland. Regional sub-groups have been formed to manage each of these networks and an officer of the Branch is a member of the Faeroes/Shetland sub-group. Another officer is a member of the COST Technical Committee for Oceanography/Meteorology which controls both Projects, 72 and 43.

The Department of Industry has placed a contract for the U.K. national data buoy DB I, and the Office has agreed to develop and provide the meteorological sub-system. The buoy is a 10-metre-diameter, high-capability discus buoy which is to be deployed in the North Sea in about a year's time. There will be a data link between the computerized shore station at Lowestoft and the Meteorological Office at Honington, at which point the data can enter the meteorological telecommunication system.

A U.K. consortium comprising the Fisheries Laboratory, Lowestoft; Institute of Oceanographic Sciences, Wormley; Directorate of Naval Oceanography and Meteorology and the Meteorological Office has been assembling a number of drifting buoys for deployment in the North-east Atlantic in the

second half of 1975. Meteorological sub-systems have been developed and built for four of these buoys which are of the small, spar type. Large drogues at a depth of between 50 and 1000 metres will provide data on currents and the buoys will transmit data to the United States research satellite NIMBUS F which will locate their positions by Doppler shift techniques. Launch of this satellite has been delayed by a year, and the time-table for the project has been similarly delayed.

The Branch played an active part in selecting, overhauling, modifying and installing instruments for the two U.K. ships chartered for the GARP Atlantic Tropical Experiment.

Comparison trials of visibility sensors which show promise for use in the economic monitoring of fog on motorways have now commenced at a site alongside the M4 motorway near Theale in Berkshire. These trials are part of a co-operative programme supported by the Home Office, Transport and Road Research Laboratory and Meteorological Office in which the latter is providing a transmissometer as reference instrument, and is also responsible for the analysis of the trials data. Some of the sensors under investigation have possible applications with automatic weather stations, both on land and at sea.

Development, production and evaluation of new instruments and systems

Installation of Mk 2 automatic Weather Observing Systems (MOWOS) was unexpectedly halted by an imposed standstill on works services; this was eventually relaxed during the summer and the opportunity was taken to install two more remote stations at Filton and Pershore, making five in all. Operational assessment of these systems by the Observational Requirements and Practices Branch has been resumed.

Approval was given for the design of an improved version of the prototype continuous automatic remote display (CARD) system to be brought to production standard, and four pre-production prototypes are being constructed for operational trials late next year.

A medium-size buoy, OBOE II, provided by the Royal Navy, is being instrumented and will be deployed, initially in the Irish Sea, late next year. The data acquisition system, like that of OBOE THAMES, uses many of the features of the CARD system.

Operational evaluation of the digital anemograph logging equipment (DALE) was nearing completion when the company supplying the magnetic-tape deck was closed without notice. Steps are being taken to select a replacement tape deck and to bring the trials to an early conclusion next year.

Development of a replacement for the Mk 5 temperature bridge has been completed and four pre-production prototypes have been built for operational evaluation. The new Mk 6 digital temperature indicator incorporates modules from the MOWOS and CARD systems and is another example of the advantages of developing a range of compatible sub-systems.

The programme for finding a suitable replacement for the existing cloud-base recorders (CBR) has been intensified. A theoretical analysis of the errors of rotating-beam CBRs has been completed and laboratory experiments have been undertaken to validate these conclusions. A prototype Mk 5 instrument has been assembled in readiness for field trials. Liaison is being maintained with manufacturers of laser CBRs, some of which may form the basis for an alternative type of replacement instrument, potentially more accurate, economic

in the use of land, but not necessarily regarded as eye-safe by national safety authorities.

The performance of the present type of high-altitude balloon has remained satisfactory, and some increase in its use is being planned to coincide with the introduction of the Mk 3 radiosonde. The latest figures can be seen in Table V. Because these neoprene balloons are difficult to launch in high winds, a new technique has been evolved in which the high-altitude balloon is inserted through the neck of an outer natural rubber balloon which provides a protective envelope at launch but bursts at moderate altitudes, leaving the neoprene balloon to continue the ascent. Performance of the present type of standard balloon has deteriorated but it is thought that the causes of this will be eliminated before long.

Analysis of data from the many equipments undergoing development trials has become a major problem in recent years, but limited software support for programming the computer processing of these data has become available during the period and attempts are also being made to record trials data in computer-compatible format from the outset.

Technical management

The monitoring of resources and the management of projects have continued to receive increasing emphasis in the activities of the Branch. Efforts are being made to provide overall planning of design, development, production, inspection, installation and maintenance in such a way that realistic time scales are established both for these activities and for the taking up of financial provisions in phase with the corresponding estimates. However, uncertainties and delays in works services, legal agreements over land, contracts and deliveries of components place practical restrictions on the usefulness of this type of planning. The use of programme evaluation review technique (PERT) charts continues to be valuable in managing complex projects and minimizes the occurrence of delays other than those mentioned above which are largely outside the control of the Office.

Technical services and facilities

Mention was made earlier of the software support now being provided for staff faced with the need to analyse large amounts of data from development trials. Increasing use of magnetic-tape data loggers, translation devices and computerized systems has required joint involvement of hardware and software experts. Studies have been made of the possibilities of using automatic data-handling methods to improve the management information systems in the Branch, and of introducing modern data-retrieval methods in connection with the storage and updating of drawings.

The technical writer, who took up post in the summer, provides additional resources for the 'in-house' preparation of technical handbooks, and also supervises the production of other documentation produced under contract by equipment manufacturers or technical writing firms.

The two optical laboratories, accommodation for which was provided the previous year, were equipped for the newly acquired responsibility for work in development and calibration of radiation instruments. By the end of the year, all laboratory work was running smoothly.

The engineering drawing office continued to be heavily overloaded, though it is still hoped that there will be a slight easing of pressure next year when work on the Mk 3 radiosonde system begins to tail off. Generally, modern systems require a much larger number of complex drawings than were needed for the simpler instruments of past decades; this makes it essential, with limited staff, to employ outside contractors. Mechanical workshops have been increasingly affected by staff shortages, and a backlog of tasks has begun to appear again.

Aerological support and advice were provided for research branches and other government departments, including the launching of experimental balloons and flying of small tethered balloons at Beaufort Park and elsewhere. A large number of flights were carried out to test samples of routine and new prototype radiosonde balloons. Technical advice was also given to MOD (Army) on their mobile steam-methanol hydrogen generator, and evaluation trials were carried out at Beaufort Park.

The Branch continued to provide technical management and staff to operate and maintain the equipment in support of the Dee Weather Radar Project at the Llandegla Research Station.

Technical inquiries from users, manufacturers, other meteorological services and government departments continued at a high level. In particular, the introduction of new equipment into service has produced many inquiries from overseas. Much effort has again been expended on the production and dissemination of specifications and other documentation needed in connection with the various aspects of the work of the Branch.

Contract liaison, equipment installation and post-design services

The continuing high level of activity in the technical progressing of requirements for the Mk 3 sonde system has been stressed in a previous section. Consideration is already being given, however, to simplifying the contractual arrangements in the next stage of procurement of radiosondes.

In addition to equipment mentioned elsewhere, two 10-cm wind-finding radars were installed, completing the programme for this equipment, and also seven data print-out systems for use with these radars. One 3-cm weather radar was installed at Newcastle and four cloud-base recorders on airfields.

The post-design services section, set up five years ago, has steadily made progress. Although most of the problems at present are associated with the older types of equipment some post-design problems are arising from equipment using modern technological devices.

Instrument testing, calibration and standards laboratory

Table XV shows the numbers of instruments and items of equipment which were tested or calibrated during the year. Exhaustive tests commenced on the first production runs from the two manufacturers of Mk 3 radiosondes. The six temperature baths for the new radiosonde calibration plant have been installed at Eastern Road, Bracknell, but the pressure calibration equipment and the automated system are not expected until the second half of 1975. The

acceptance testing programme also included the remainder of the MOWOS equipments, further modernized facsimile recorders and a large number of magnetic-tape event recorders.

The facilities for the calibration service have been improved by the addition of an oscilloscope calibrator. Increasing attention is being given to the problems of carrying out check calibrations of instruments in the field, particularly of sensors used with the new generation of unattended automatic weather stations. Examples are the alignment of wind vanes connected to runway cross-wind resolvers, cup anemometers which need to be tested as part of a complete wind system, pressure transducers, tipping-bucket rain-gauges, rate-of-rainfall transducers and sunshine transducers.

The main change during the period was the completion of the arrangements for the calibration of radiation instruments at Beaufort Park, responsibility for which had been transferred from Kew in 1973. The growing importance of accurate measurements in this field has recently been re-emphasized in connection with the monitoring of atmospheric pollution and the utilization of solar energy. Three types of measurement are involved. An Ångström pyrheliometer is used on cloudless days to calibrate one or two selected pyranometers which are then used in turn to calibrate the field pyranometers in a uniformly diffusing hemisphere in the laboratory. Net pyrradiometers are calibrated in the laboratory against a tungsten-halogen lamp which is regularly checked against an Ångström pyrheliometer. The third type of instrument is the illuminometer. A standard lamp, calibrated at the National Physical Laboratory, is used to calibrate a selected illuminometer which is then used in the diffusing hemisphere to calibrate field instruments.

Servicing and technical training

The quantity and complexity of equipment being maintained in the field has steadily increased, and servicing methods and technical support procedures are constantly under review. At the beginning of the year fuel restrictions added considerably to the difficulties, but a satisfactory service was nevertheless maintained. It was fortunate that the computer model of the Regional Servicing Organization, referred to last year, was available by this time. This showed that there would be some advantage if 18 of the 310 stations with equipment were in future serviced by other centres. By making these changes, and also by using Meteorological Office technical staff at MOD(PE) stations to service equipment in their area, with the agreement of the parent branch, a saving in travel of about 9000 miles per annum, and a reduction of over 300 man-hours per annum, have been achieved.

Further savings could be made by establishing a servicing centre in the north of Scotland and possible sites are now being considered. The existence of a centre in this area would permit a much quicker response to emergency calls in the areas of northern Scotland. In order to even out the work-load at Regional level, responsibility for the Newcastle area was transferred from the Midlands Region to the North Region.

Practical studies to reduce the cost of preventive maintenance have continued. With the exception of equipment at upper-air stations, it has proved possible to limit routine servicing visits to outstations to four per year. It has

been necessary to observe closely the results of these experiments, and to introduce more effective methods of monitoring the technical status of the 700 equipments in the field.

Initial training of technical staff at R.A.F. Sealand has been extended to 7 months in order to enable trainees to take the fourth-year City and Guilds telecommunication examinations. Subsequent practical training of technical staff continues to be provided at Beaufort Park. The course at Beaufort Park covers most of the operational electronic meteorological equipment currently in use, and is followed by 3 months' practical field training before the trainee undertakes full servicing duties in the field. In addition, short courses are given to experienced staff to cover new equipment going into service.

Since most equipment now being developed is based on a number of functional modules, a change in the emphasis of teaching methods has been introduced whereby the overall characteristics of each module are examined rather than the detailed behaviour within the module. This approach will be used for training technicians to maintain the Mk 3 radiosonde system.

Computing and Data Processing

The Data Processing Branch is responsible for operating the IBM 360/195 scientific computer, the processer-controlled key-to-disc data-entry system and the punched-card unit. It provides the software needed for computer operation, including operation of typewriter and cathode-ray-tube terminals, and the programs within the IBM 360/195 to interface with the telecommunication system. The Branch is also responsible for general-purpose programs to store, quality-control, and retrieve observational data received from the telecommunication systems and to produce plotted and line-drawn charts and graphical displays required mostly for day-to-day operational tasks. An Enquiry Bureau maintains liaison with computer users, offering advice as required, and provides a limited service of data extraction from machinable archives.

Meteorological Computing Laboratory

During 1974 most of the resources of the Branch were directed towards the acquisition and implementation of a second computer system to be linked with the existing IBM 360/195. In addition to supporting an extended remote-terminals service, the second system will have sufficient power for many of the smaller computing tasks and will release the IBM 360/195 for the more demanding work. Also, although having only about one-tenth of the power of the main processer, the second system will not only provide the computing power for line drawing and plotting but will be just fast enough to provide a back-up forecast service on site when the IBM 360/195 is unserviceable. A second IBM system was chosen because it can be linked directly to the IBM 360/195 and operated with no increase in operating staff; also, programs written for the IBM 360/195 will run on the new system without the need for reprogramming in another language.

The selected system is a virtual storage IBM 370/158 with two megabytes of real storage and eight additional disc drives, making 20 drives in all. All 20

disc drives, the fixed-head disc and the six magnetic-tape drives are connected so that they are available to both the IBM 370/158 and the IBM 360/195 computers which are loosely coupled to each other. No additional input or output devices were ordered with the IBM 370/158 and the coupled processers run under an operating system which allows all input and output for both processers to be made from the existing devices. During normal operations the input and output devices are connected to the smaller processer but a special switching unit allows the input/output devices to be switched to the IBM 360/195 if the IBM 370/158 fails.

Preparation for the new system commenced in January with the development of a time-sharing system for terminals (TSO) for experimental purposes. In March work started on the three operating systems which will be required for the two processers; the Asymmetric Multiprocessing System (ASP) to control the flow of work to and from both processers, the Virtual Storage system (VS2) to control the work in the IBM 370/158 and the Multiprogramming System with a variable number of tasks (MVT) in the IBM 360/195. In developing these systems full use was made of the development time provided as the IBM test centre, Croydon, where most work was done overnight in dedicated 'hands-on' sessions on an IBM 370/158, but it was also necessary to take over the IBM 360/195 on most Wednesday mornings and for periods at most week-ends. By September operational versions of ASP and VS2 were generated for use at Croydon and were used during 'hands-on' sessions to provide advance training for Shift Managers and Console Operators. The IBM 370/158 was delivered on 20 November but delivery of the 'string' switching facility, which makes all 20 disc drives available to both computer systems, was delayed and the eight new disc drives were connected temporarily to the IBM 370/158 by means of a third disc controller on loan.

Hardware performance of the IBM 360/195 system was generally good during the year but a central processer failure on Friday, 1 March caused a major breakdown lasting 80 hours and required the services of IBM engineers from their main plant at Poughkeepsie, U.S.A. This breakdown necessitated six consecutive forecast back-up computations on the IBM 360/195 at the Rutherford Laboratory.

Rutherford Laboratory work was seriously disrupted and the Office is greatly indebted to its staff for their substantial help and forbearance. The major failure in March served to emphasize the importance of the on-site back-up facilities which will be available after the new IBM 370/158 system is fully operational. A magnetic-disc head crash on 1 July required the inspection of all discs in current use. Also, five hours of operation were lost in June following overheating and failure at the main electricity distribution panel which in turn precipitated a central processer failure.

Changes were made to the Synoptic Data Bank (SDB) routines to improve their effectiveness. These included additional quality-control checks and retrieval routines for SYNOP, SHIP, TEMP and PILOT codes and extra quality control for Satellite Infra-red Spectrometer (SIRS) data. Also modifications were made to storage and retrieval routines for Chinese upper-air data, and satellite-derived upper winds. The current SDB is designed to receive data at discrete intervals by means of paper tape but the latter will be replaced early next year by an IBM System 7 computer interface between the telecommunication computers and the main computing complex. Data can flow

almost continuously through the interface and detailed planning, with some exploratory programming, has started on a suitable permanently resident SDB.

The Synoptic Data Bank team were given responsibilities for collection and storage of synoptic data required for the GARP Atlantic Tropical Experiment (GATE), and the SDB team leader represented the U.K. at the GATE data management meeting in Washington from 4 to 8 February. Data for the GATE area transmitted on the Global Telecommunications System (GTS) during the GATE period were stored in the Synoptic Data Bank for subsequent transfer to GATE data sets by the research team working in the Dynamical Climatology Branch and regular inventories of data were transmitted through GTS to the GATE Operational Control Centre (GOCC) in Dakar during the period of the experiment. The SDB team also despatched 8000 special boxes to countries participating in the GATE project, for collection of paper tapes holding GATE data. These data were transferred to magnetic tape by using the PDP 11/40 computer and sample checks have indicated that the paper-tape data have added considerably to the data received through telecommunication channels. Surface observations from the two U.K. chartered vessels were in manuscript form and were transferred to punched cards.

The operational line-drawing and plotting programs developed during 1973 were extended further. Plotting of Satellite Infra-red Spectrometer (SIRS) data was included and an automated plotting schedule was introduced in February covering 24 hours per day, providing some of the services required by the Central Forecasting Office (CFO) and facsimile transmissions to outstations. This service was designed primarily to test automated plotting services under operational conditions and as such proved successful; but CFO was compelled by staff shortages to rely on it at times before its development was complete, and before sufficient equipment was available to cover breakdowns. There were three known weaknesses: slow reception of hourly U.K. data, lack of an alternative computing source on site, and insufficient redundancy in the plotting equipment. Reception of the U.K. data will be speeded up when paper tape is replaced by the interface being developed to connect the telecommunication computers to the main computing complex. A second source of computing power is available on site now that the IBM 370/158 is installed. There is sufficient redundancy in the two 1136 drive plotters to maintain the operational service of large plotted charts but a second device, comparable with the existing Calcomp 1670 COM equipment, is required to back up the service of smaller plotted and line-drawn charts which are produced in large numbers for CFO and for facsimile transmission to outstations. Alternative equipment, including a laser-driven device, was carefully considered but there is a very limited range of equipment capable of producing charts of sufficiently high quality for facsimile transmission and fast enough for the high volume production required operationally in CFO. Also, it is essential that the second plotting device is fully compatible with the Calcomp 1670 equipment, that the same computer main-frame plotting programs should drive both devices and preferably that this compatibility should also extend to the programs in the controllers of the two plotting devices. For these reasons a second Calcomp 1670 device was ordered for installation in March 1975.

In addition to its use for operational forecast output and for general research purposes, the line-drawing and plotting equipment is being used by several

branches to produce scheduled output of a semi-operational nature. For example the Agriculture and Hydrometeorology Branch produces maps of evapotranspiration of moisture and monthly rainfall and the High Atmosphere Branch produces 50-mb, 20-mb and 10-mb plotted charts for synoptic studies of high-altitude data.

Comparatively few major changes were made to the numerical forecasting suites by the computer programming teams attached to CFO but many improvements were made to the recovery procedures throughout the suites to make operational procedures easier. In August the 'rectangle' suite, which provides forecast guidance for the British Isles area, was rescheduled to precede the 'octagon' suite, which covers a much larger area for aviation purposes. The new schedule was a tight one but was eased by the introduction of faster computational techniques in November.

Two series of analyses and forecasts were run on a semi-operational basis during the year. The first series was run in March and May on behalf of the Forecasting Research Branch and was designed to assess the operational importance of ocean weather ship reports and of satellite data. The second series was run during the GATE operational period 26 June–20 September and was designed to test techniques of analysis and forecasting for the GATE area. The extra computing time required for this special work was made available by the temporary cancellation of terminal operations and certain job classes.

The work-load for the IBM 360/195 continued to grow during the year and by the end of the first quarter a backlog of work began to build up during mid-week periods although it was cleared at most following week-ends. By June it was necessary to introduce a priority system whereby branches could select up to 10 per cent of their work for priority handling. The priority system enabled branches to control the progress of their more important or urgent projects but by July the still-growing work-load made it necessary to introduce a stringent rationing system for batch work, effectively limiting branches to the amounts of computing used by them in the first five months of the year. The severe rationing caused considerable difficulties for those branches which relied on regular output from computer programs to discharge many of their routine responsibilities and, towards the end of the year, it was necessary to transfer such work to a special operational class where their computing requirements were insulated from the effects of rationing.

Work on the special version of the Conversational Remote Job Entry (CRJE) software package to support remote-terminal operation using much-reduced main storage was abandoned because the steadily increasing work-load made it unlikely that the service could be extended even with the reduced storage requirement. The extended CRJE, written by the remote-terminals team to provide support for visual-display terminals (VDU), was sold to two commercial firms. Developments continued on the support for graphics terminals, including a program to display sequences of plotted observations for use in CFO. The main work of the remote-terminals team was concentrated on developing new supporting software (TSO) for the terminals to be attached to the new IBM 370/158 computer which will have sufficient storage to support a terminal service throughout normal working hours. Authority was given in September for the purchase of additional visual-display units and for a transmission-control unit (TCU) capable of attaching, by means of leased or

dialled telephone lines, visual-display units remote from the main headquarters building. The TCU can also be used to attach the PDP 11/40 computer to the main system.

Punched card and processer-controlled keying installation

The punched-card pool was re-equipped in the early part of the year with IBM 129 programmable punch/verifiers for use by the full-time punching staff and the older 029 punches were transferred to the self-service area where they served to reduce the customer queues formed in busy periods.

The processer-controlled key-to-disc (PCK) installation performed well, with a good record of serviceability and a stable staffing level permitted consolidation of expertise amongst the operators.

The run-down of the old punched-card machine room continued. An additional programmer was provided in the Enquiry Bureau partly for formatting tasks on the PCK equipment and also to undertake the remaining punched-card output by program on the main-frame computer. Card reproduction is still required but the reproducer has been transferred to the IBM punch pool and the work is done by the machine operators in that area. Hire of ICL punch-room equipment ended in September and all other equipment belonging to MOD was transferred to other government departments or made ready for disposal.

Systems Development

The year 1974 was the fourth in the life of the Branch which was established to promote the application of systems concepts to the work of the Office and to develop appropriate, usually computer-based, systems to this end. The year was one of consolidation or initiation of previously conceived projects, although a start was made on one or two new ones.

The highlight was the installation early in the spring of a mini-computer system equipped to serve many different purposes. However, the bulk of the effort continued to be developed to the build-up on the central computer (the IBM 360/195) of the national archives of meteorological data in machinable forms together with an associated library of computer programs to handle them, with some special emphasis on data editing and retrieval via visual display units (VDU).

Machinable archives

Historic meteorological data comprise many different types (marine, land surface, aerological, research, etc., British and foreign), some spanning the epoch from the early nineteenth century, or before, to the present day. They exist, and are still being produced, in a large variety of forms and media, including manuscript records, autographic traces, punched cards, paper tapes, magnetic tapes (of several sorts, some non-standard), etc., collectively amounting to more than 10 000 million values of discrete elements (pressure, temperature, wind, clouds, weather, etc.). These are being augmented at an ever-increasing rate because of the growing number of (international) observing stations and, more significantly in terms of volume, because of new automatic recording techniques (field logging, satellite sensing, electronic digitizing, etc.) which have widened further the range of types of data and media.

Apart from their diversity of type and sheer volume, meteorological data tend to be very inhomogeneous, having been subjected to many different coding conventions, instrumental standards, modes of collection and units of measurement over the decades. Also the traditional methods of arranging records and of organizing files, of classifying and cataloguing, of checking and correcting, and of processing (including publishing) and retrieving, were adapted to past management procedures and machine methods. All have had to be revised in the computer era, even while the data were in day-to-day use for research purposes and in climatological services. Understandably the result has been, and will continue to be, a rather slow evolution towards a better-ordered, more refined and more readily accessible data bank.

From the time when the IBM 360/195 became the main meteorological computer facility, the requirement has been to convert all data files to half-inch magnetic tape (9-track, 1600 bits per inch) which is the preferred processing and storage medium and is also one of the standard forms for international exchange in Meteorology. Most of the U.K. surface climatological and rainfall data that were on cards, paper tape or three-quarter-inch magnetic tape (used on the previous computer) have now been transferred to the more accessible formats. Marine data from world-wide British merchant shipping, going back to 1854, have been punched on cards regularly since 1921, and have now been read successfully to magnetic tape; they were being sorted into order by the end of the year and programs are being developed to re-order them into the more accessible formats. There is still, however, a sizable backlog of ships' data, probably more than a million observations, still waiting to be punched and these include many from sailing ships which travelled many different routes no longer traversed by steamships. All these marine data will be merged with a large acquisition from the American National Climatic Center of over 35 million ships' observations covering the period 1845–1968 (300 reels of magnetic tape at 800 bits per inch).

Data and information retrieval

The usual method of accessing magnetic-tape records on the central computer is first to transfer them sequentially to a magnetic disc, from which they can be read into the computer memory at very high speed in the original order, and at reasonable speeds when required in some other order or at random. To enable (FORTRAN) programmers to access data on disc easily and efficiently, two access routines were specially designed, one called GPACCESS to handle records that are fairly constant in length, the other VACCESS for variable-length records. These use the indexes built into individual data sets to retrieve precisely those items required and present them in the specified memory locations. They have been in constant use for more than a year.

Once data are in computer memory they can be readily processed and presented by normal programming methods. One device that has not yet been widely exploited within the Office is the VDU keyboard-terminal and associated light-pen. A program routine called TALKBACK, which was also specially written within the Branch, has been further amplified and put into limited operational use for the display and editing of some classes of data in archives. These applications are likely to increase when the recently installed IBM

370/158, with its improved terminal and more efficient retrieval facilities, comes into service.

One interesting application of VDUs is to allow users to interrogate and to display up-to-date information relevant to the file they wish to process, as well as the data themselves. For this purpose master catalogues have been compiled on disc of such basic information as station names and/or number, positions, heights above sea level, dates of commencement and cessation, which together with data formats and other indexed material contained in each file will provide users with most of what they need to know about the data. These catalogues will continually be updated as more information (e.g. on the site exposures or the instrumentation) is coded and as stations become defunct or new ones come into operation. Such a facility on-line will powerfully supplement the existing printed catalogue which is only published annually and in which it is not feasible to include anything like the total volume of information. For example, there are nearly 11 000 British rainfall stations already in the master (machinable) catalogue, 7000 of them still extant, with a yearly turnover of some 2–3 per cent of the sites.

Headquarters mini-computer

The computer is a DEC PDP 11/40 comprising 16 K (K = 1024) words of memory, a teleprinter console, a magnetic-tape deck (compatible with the IBM system), a magnetic disc, a card reader, a paper-tape reader, a Versatec electrostatic printer/plotter and a GT40 graphics terminal, with cathode-ray-tube display keyboard and light pen. There are also two special replay decks, one by Epsylon and the other by 3M, able to handle the non-standard magnetic-tape cassettes used to log data in the field.

In addition to its main role as a translater to IBM-compatible forms of field-logger cassettes, the system is being used as a general testbed for a variety of projects and special exercises. These range from the short term and the specific, e.g. the conversion of telecommunication and GATE paper tapes to magnetic tape (the former as a standby measure in case of failure of the IBM 360/195), to the long term and the general, e.g. studies of what sort of 'intelligent' terminals might be required at main meteorological centres and outstations of the future, including interactive graphics and new forms of data presentation.

One advantage of mini-computers is that a whole range of novel devices may easily be attached to them. For example, equipment to implement an automatic network control experiment of the Meteorological Office Weather Observing System (MOWOS) on the PDP 11/40 will be fitted early in 1975. The project will involve the automatic dialling via telephone lines of a number of MOWOS stations in the field, the data from which can be collected, checked and centrally stored every few minutes, under program control.

Automatic trace analysis

Many meteorological data are produced in analogue forms on autographic pen-and-ink traces. For example there are in existence about 6 million daily rainfall charts from about 400 sites, a few going back more than 50 years. Although an attempt was made a few years ago to digitize these by semi-manual means, progress was impossibly slow and more automation was sought.

The most effective device found was a computer-controlled flying-spot scanner at the Nuclear Physics Laboratory, Oxford University, used primarily for the analysis of bubble-chamber photographs. Over the last two years, largely because of the co-operation and efforts of the staff of the Nuclear Physics Laboratory, a successful system has been developed and is now operational to read automatically a selection of these rainfall charts; some $1\frac{1}{4}$ million charts are being converted to 16-mm microfilm, required by the scanner. The output is on magnetic tape and comprises a point-by-point representation of the original traces together with derived hourly amounts and durations of rainfall. Checking and correcting of the tapes uses both the IBM installation and the headquarters mini-computer and entails the use of the GT40 terminal to re-create and display suspect traces as they were read, simultaneously with relevant hourly statistics.

Although only rainfall charts are being analysed at the moment, many other forms of trace could be tackled and some initial attempts to read the much more complex autographic wind charts by the same means have been encouraging.

Library accessions system

The implementation of a new system to handle the 10 000 or so annual accessions to the Meteorological Office Library began in earnest in the autumn. This followed earlier feasibility studies which showed the inefficiencies of the present paper-tape-based techniques of editing and cataloguing the incoming books, periodicals and papers compared with computer methods. All these have to be classified and listed into as many as eight bibliographies and catalogues altogether totalling some 4000 entries every month—and the numbers are increasing steadily year by year.

Although at the time of writing the design of the system has not been finalized, it is likely to utilize the disc storage and hard-copy output facilities (the latter including both the Calcomp microfilm plotter and a line-printer with a special range of printed characters) of the IBM 370/158, but with the prime data entry and editing via an attached mini-computer controlling a number of VDU keyboards. Such a configuration, given suitable supporting software, would be capable of extension to provide rapid retrospective searches throughout the growing bank of information (preserved on magnetic tape since the beginning of 1972) and opportunities for improving the loans system.

Miscellaneous projects

The various enhancements in the headquarters computer complex have opened up a range of possibilities at outstations (terminals and computer-to-computer networks). For example, the postal collection of climatological data for Scotland and Northern Ireland is via Edinburgh and Belfast, respectively, although they are keyed and checked by computer methods at Bracknell, with subsequent exchanges by post and telephone to determine corrected values. The streamlining of this procedure through the use of suitable terminals and telecommunication links is being studied.

Similar connections with the Principal Forecasting Office at Strike Command are also being considered, possibly requiring a more elaborate computer-controlled system there because of the wider range of functions (synoptic

plotting, contouring and telecommunication traffic handling) that may benefit from automation.

The non-machinable archives, housing most of the Office's records in hard-copy forms (registers, logbooks, charts, aerological diagrams, etc.), are increasingly requiring data on microfilm and microfiche, especially since the installation of the Calcomp microfilm plotter in headquarters. This led to a reopening of the question of microfilming more old records, which in the light of recent advances in techniques and in the design of access devices may thereby become more secure and more usable than hitherto. A study report on the subject was completed late in the year.

Meteorological Telecommunications

The predominant feature in meteorological telecommunications has been the continued steady progress in the application of automation, and this has been evident throughout 1974. This is true whether one looks purely at the U.K. national scene, or the wider WMO scene. In terms of the latter, this could be said to apply from Japan, across North America and through most of Europe, with stirrings occurring in Africa and Asia. The Bracknell Regional Telecommunication Hub (RTH) has become fully established in its role on the Main Trunk Circuit (MTC) of the WMO Global Telecommunication System (GTS), and by virtue of its geographical position Bracknell is seen as the 'gateway' centre between Europe and North America. Implementation of the planned new European Meteorological Telecommunication Network (EMTN) has moved some way forward. Although in its final form it will consist mainly of automated nodal centres interconnected by high-speed data-transmission systems, certain interim steps have been taken to make these connections to the Bracknell RTH first by means of low-speed teleprinter circuits. A basic philosophy, agreed internationally some time ago, was that no new system would be introduced and the existing system swept away until it was quite certain that the new one was effective and could assure continuity of service (see Plate IV). This philosophy has been applied equally to the U.K. national organization. A major problem has been, and still is, that of maintaining a continuous operational service while existing systems are closed down and the new ones take over the operational role.

Bracknell automated telecommunication system, Phase II

The original contract with the Marconi Company to produce and install an automated system at Bracknell as the heart of the new RTH allowed for this to be done in two distinct stages. The first, known as Phase I, was planned as an interim measure and therefore provided only limited facilities and services. Phase I was delivered in mid 1971, accepted from the contractor in January 1972, moved to the new Richardson Wing in mid 1972 and placed in operational service on the main trunk connection with Washington in November 1972. It was not until April 1973 that the MTC, from Washington through Bracknell and Paris to Offenbach, became fully operational on high-speed (2400 bits/s) data transmission and analogue facsimile, and the Phase I automated system was at last doing the job it was designed to do. In the meantime the Phase II automated system was being developed and factory tested, mainly as regards

its software, the hardware having been present for quite some time. Phase II was designed to provide all that Phase I could do, and much more as well. It would provide facilities for additional international data speed connections, but above all Phase II was designed to introduce the first major impact of automation on meteorological offices in the United Kingdom, and also to automate quite a lot of the manual telecommunication work performed at the Bracknell RTH.

In January pre-installation work was started in the automated complex, ready to accommodate the hardware. Unfortunately the national industrial troubles and the three-day week in the early part of the year had their effect on completion and delivery of the Phase II system. A delay of several weeks became unavoidable. The hardware was eventually delivered and installed by the Marconi Company during April. Acceptance testing proceeded very smoothly and the whole system was formally handed over to the Meteorological Office on 26 June. By August the U.K. area centres responsible for collecting the hourly observational reports had been connected to the new system (in parallel with the normal teleprinter terminal equipment) in order to feed into it 'live traffic' originating in the national network. Meteorological bulletins from the main trunk had already been used for testing purposes, but it was necessary to discover how it would respond to the reports as received directly from the area collecting centres. The automated system was designed to check bulletin format and correctness of operating procedures, and to transfer to a reject position all those deviating from the standardized format and procedures: happily the rejection rate was much lower than expected.

Commissioning of the Phase II system to full operational service is a lengthy process, and from the start it was expected to take several months. A number of its facilities and services have of necessity been introduced piecemeal owing to acute staff shortages; only by using the automated system to plug the staffing gaps has it been possible on many occasions to maintain continuity of service. These shortages were due to the variety of reasons which account for normal wastage, but several teleprinter operators resigned because of a fear of redundancy as automation became more obvious. Although the commissioning process has been particularly concentrated on those facilities and services directly related to the Bracknell RTH itself, the process will not be considered as completed until each U.K. area collecting centre (and its associated stations) has its own preferred order in the content and timing of the data transmitted to it. In fact each centre will be able to specify any one from a choice of three U.K. data transmission programmes, each programme being related to a particular weather pattern affecting the United Kingdom or adjacent areas of Europe and the North Atlantic. The Phase II system is not expected to become the primary automated installation at Bracknell until some time in 1975.

Further expansion of the automated telecommunication system

As explained in the *Annual Report* for 1973, it became clear late in 1972 that Phases I and II of the telecommunication automation programme would not be adequate to enable the U.K. to fulfil its obligations to participate in international plans for the extension of automation to the European network. The situation arose partly because the design of Phases I and II systems was based on the technology of 1967–68 and partly because of changes in the international requirements. Accordingly, it was evident that a substantial

expansion of the automated facilities would be necessary. It was agreed with the Ministry of Defence Procurement Executive (MOD(PE)) that first a limited number of firms should be given outline information about the requirements and invited to bid for a Project Definition Study (PDS) contract. The outcome was that two of the firms consulted, Ferranti and Honeywell, were awarded contracts to conduct Project Definition Studies and these were completed in July of this year.

The tenders for the production contract were received in mid August but these were subsequently revised to allow inflationary aspects to be covered in accordance with special contractual conditions. In due course the production contract for the project was awarded to Messrs Ferranti and it is hoped that delivery of the enhancement sub-system will be made around the end of 1976 or early in 1977.

Provision of electronic interface between the Telecommunication Centre and the Computing Laboratory

One of the known deficiencies of both the Phase I and Phase II systems of telecommunication automation at Bracknell was that of providing a direct high-speed electronic interface between the Myriad II computers in the Telecommunication Centre and the IBM 360/195 in the adjacent Computing Laboratory. The main enhancement, as defined in the user requirement, includes this interface as an essential feature. But as soon as it was evident that procurement of the enhancement sub-system would be a project of at least 2–3 years duration, an interim solution for providing a high-speed direct interface was obviously necessary. A short but intensive study showed advantages in the use of an IBM System 7 computer for the main part of the interface, and leasing the System 7 for a year or two as the quickest and most economic way of doing it. The study also considered the establishment of a 2400-bits/s connection with the Brussels National Meteorological Centre (NMC), and it showed that a teleprocessing unit associated with System 7 could conveniently provide this connection.

The System 7 computer was delivered to Bracknell at the end of May. For some time before this the telecommunication software team had been developing the special software needed to operate the interface, and special hardware had to be designed and produced locally in order to connect the System 7 to the Myriads. The task of establishing the complete interface proved to be more difficult and time-consuming than had been anticipated. The interworking of the System 7 and the 360/195, both being IBM products, was achieved without much difficulty. It was, however, a different story as regards achieving compatibility of operation between the System 7 and the Myriads; this was not achieved until late October.

Implementation of the Region VI EMTN Plan

Although the new European Meteorological Telecommunication Network (EMTN) is based on a plan approved by WMO Regional Association VI (Europe), it forms a part of the integrated GTS. Like the global system in concept, it consists of a number of primary nodal centres (the RTHs) and an interconnecting high-speed network including the NMCs. Already the Bracknell RTH is connected to the Paris and Offenbach RTHs by circuits operating at

2400 bits/s and passing analogue facsimile charts on a time-division basis. The EMTN plan makes provision for the Bracknell RTH to have direct high-speed connections to the NMCs of Brussels, De Bilt (Netherlands), Copenhagen, Oslo, Reykjavik and Dublin.

For some time the Bracknell–Oslo connection has been operated on an interim basis by the use of four teleprinter circuits between the two centres. Arrangements for the planned EMTN 1200-bits/s connection were made during the year and trials of the new circuit between the Bracknell RTH and Oslo NMC at 1200 bits/s began in November.

In January the Bracknell–Reykjavik connection was established on an interim basis using a direct teleprinter circuit. The high-speed connection is not expected to be established before 1976 or 1977 when the Reykjavik NMC should have the necessary automated facilities. Bilateral meetings were held between the United Kingdom and the Netherlands and between the United Kingdom and Belgium to plan the arrangements for the higher-speed circuits required to be established with those countries under the EMTN plan.

In order to progress more effectively the implementation of the overall EMTN plan, a co-ordination meeting of representatives of all the European RTHs and certain key NMCs was held in Geneva in December.

Telecommunication aspects of GATE

As was mentioned in the Report for 1973, staff had been involved in the earlier telecommunication planning for the GARP Atlantic Tropical Experiment (GATE). This involvement was not only with GTS aspects, but included ship–shore and air–ground communications as well. A telecommunication expert from Bracknell also attended the Geneva meeting held in April to finalize the telecommunication plan for the whole of the GATE operation.

The GATE operation was scheduled to take place from June to September. During May a considerable volume of message traffic concerning final preparations for the operation was handled by the Bracknell Telecommunication Centre, much of it being produced by the Bracknell-based international planning staff. Direct reception of the Nairobi radio-teleprinter broadcast was maintained over the GATE period, and data received over the direct Episkopi (Cyprus)–Bracknell radio communication link were regarded as useful sources of observational data related to GATE. A twice-daily bulletin giving an inventory of missing data was transmitted from Bracknell to the Control Centre in Dakar throughout the operation.

Developments in facsimile readout of U.S. observational satellites

December 1974 saw the sixth birthday of the American ESSA 8 weather satellite. It is the last U.S. observational satellite to provide the relatively simple automatic picture transmission (APT) service, and throughout the year APT pictures from ESSA 8 have been regularly received and distributed to the Central Forecasting Office (CFO) and selected key offices in the U.K. Some of the offices overseas, such as that in Gan, have their own independent ground station.

The American NOAA 2 and NOAA 3 satellites use scanning radiometer (SR) techniques, and provide cloud pictures in the visible range and also in the infra-red spectrum. The SR transmission, as recorded on the normal type of facsimile machine, results in a narrow picture with severe distortion occurring

towards the edges. It was mentioned in last year's *Annual Report* that the effect of this unwelcome presentation could be reduced by 'stretching' the recorded picture, or virtually eliminated by the application of electronic linearization.

In the earlier months of the year means to achieve either stretched or linearized recordings were given much attention but owing to serious difficulties with the equipment, both recorders and a prototype linearizer, little progress was made. Accordingly a more fundamental search had to be made to find a replacement satellite-picture recorder. Hawker Siddeley Dynamics (HSD) have under development an 18-inch Mufax recorder modified so as to produce stretched visible and infra-red images side by side. A series of field trials of a prototype of this recorder was mounted, including meteorological evaluation at operational level in CFO. Indications are that this HSD modified Mufax machine may well meet the meteorological need and also the telecommunication requirement for a replacement satellite-picture recorder.

Coded digital facsimile

Analogue facsimile has been used by the Office for over 20 years, initially on a national basis, but once the technical characteristics of weather facsimile transmissions were standardized by WMO, its international usage spread fairly rapidly. There is no reason to suppose that analogue facsimile as a meteorologists' tool will not continue to be used for many more years. But problems arise when one wishes to transmit pictorial information between computer-controlled automated telecommunication centres over digital data transmission connections. Analogue facsimile in this area tends to appear as an anachronism; digitized facsimile appears more attractive and acceptable. However, without coding compression the attraction is illusory.

In January an engineer and a scientist were sent to the Washington World Meteorological Center on a fact-finding mission to ascertain in detail the American developments and intentions as regards coded digital facsimile. They were able to obtain a full assessment of the hardware and software requirements, as well as the likely costs and impact on the Bracknell RTH should a decision be taken to introduce coded digital facsimile operations. At the Sixth Session of the WMO Commission for Basic Systems (CBS), held in Belgrade in March, there was some discussion on this subject and the possible future potential within WMO, and also on the level of need in relation to other ways of transmitting pictorial information, particularly by use of the grid code and analogue facsimile. The CBS decided that its telecommunications working group should study the subject further. In the meantime the U.K. experts are in consultation with their colleagues in the U.S.A., France, Germany and Japan regarding future developments in coded digital facsimile.

Analogue facsimile recorder—replacement programme

Progress with the replacement programme for the analogue facsimile recorders has been frustrating and disappointing. The firs prototype recorders were delivered as long ago as March 1973, and it has taken over 18 months of trials and consultation with the manufacturers to eliminate the technical problems, not least those associated with operation at 240 rev/min. By the end of 1974 success had at last been achieved and the replacement programme, affecting all offices throughout the United Kingdom, began.

Special VAP telecommunication project for Iceland

Under the WMO Voluntary Assistance Programme (VAP) the Office has continued to provide assistance in terms of finance and equipment for several countries, with telecommunication equipment filling a significant part of the aid given, or planned to be given.

The largest and technically most complex of the VAP Projects currently in hand is modernization and automation of the Reykjavik NMC telecommunications; this is of considerable importance to the United Kingdom because of the need to obtain Greenland and Icelandic observations speedily. Owing to its size and technical complexity it is an expensive project; it is therefore being shared jointly by WMO, Iceland and the United Kingdom, with perhaps some American assistance as well. The user specification has been produced and agreed by WMO and Iceland. A small informal planning meeting was held at WMO Headquarters in Geneva in September to discuss ways and means of implementing the Iceland project. It was agreed that the WMO Secretariat would act as the overall management body, including dealing with contractual and financial aspects. On the other hand the Meteorological Office would provide the professional and technical expertise in terms of system design, production aspects, acceptance testing and commissioning.

General comments

The past year has been a very busy and challenging time for those concerned with telecommunications in the Office. In addition to areas of work already described, much effort has been absorbed in reviewing the efficiency and economic viability of existing telecommunication facilities and services. This applies not only in respect of offices spread throughout the United Kingdom, but those serving British Forces overseas as well. Tentative plans have been prepared for an up-to-date telecommunication system linking Bracknell and the ocean weather ships. Contact has been maintained with telecommunication developments in the fields of other international bodies such as the International Telecommunication Union and International Civil Aviation Organization.

International and Planning

The development of meteorology and its applications continues on a broad front, internationally as much as nationally. International co-operation is indispensable for daily operations in many fields and there is a need to share experience for mutual benefit. The World Weather Watch (WWW) of the World Meteorological Organization (WMO) comprises the basic system for observation, collection, storage and distribution of data for all general service purposes; and the Global Atmospheric Research Programme (GARP) organizes a comprehensive attack on the main large-scale problems of meteorology. There are many other research problems and specialized arrangements for specialized services, besides these major programmes. While most of this work is associated with WMO, there are significant meterological programmes associated with the International Civil Aviation Organization, the North Atlantic Treaty Organization and in the field of European co-operation, and several Specialized Agencies of the United Nations have meteorological elements

in their programmes. One of the main functions of the International and Planning Branch is to handle these general international matters, largely as a co-ordinator and as a channel of communications.

World Weather Watch (WWW) is a world-wide international system composed of all the national meteorological systems of the world. To develop WWW further to meet changing needs, the related activities of planning and implementing the system, and monitoring its performance have to be carried on simultaneously. Planning is carried out by the constituent bodies and Secretariat of WMO in a 4-yearly cycle. There was much activity early in the year in preparation for the Sixth Session of the Commission for Basic Systems where the current plan was revised to take account both of developing technology and the changing concepts of WWW. Monitoring is carried out by the WMO Secretariat, who call for annual detailed status reports from all Members and also ask selected centres, including Bracknell, for surveys in specified periods of the meteorological traffic passing on the Global Telecommunication System. Although the Bracknell Centre is largely computerized, the traffic survey involves a substantial work-load. The annual status report also requires information to be obtained from many parts of the Office, and on all meteorological activities in overseas dependencies, on the high seas, in the Antarctic, and in outer space.

The implementation of WWW is the responsibility of the Member countries of WMO. In the United Kingdom itself implementation is at a very high level in order to meet national requirements, and on the high seas British merchant ships and weather ships have long formed a large proportion of the total weather-reporting fleet. Observing stations are now seen to be required for WWW on some small U.K.-dependent ocean islands. The International and Planning Branch has the task of organizing such stations. The upper-air stations established in recent years in the Pacific on Tarawa and Funafuti (Gilbert and Ellice Islands), and also on Efate in the New Hebrides were maintained as before. The New Zealand Meteorological Service operates the Tarawa and Funafuti stations as our agent with the help, on Tarawa, of a Technical Officer from the Office. The New Hebrides station is operated by the Condominium Meteorological Service and costs are shared between the United Kingdom and France. For the intended upper-air station on Mahé, in the Seychelles, little progress was possible until late in the year while a legal problem over the selected site was being settled. About a year's delay has resulted. On completion the station will be operated by the Seychelles Meteorological Service. Planning of the St Helena upper-air station has gone ahead steadily, including provision for a direct radio link to Kano, Nigeria for sending meteorological reports.

As regards surface observing stations, arrangements were agreed with the Royal Society to increase the number of reports made at their base on Aldabra Island from 1 to 8 per day. Study of the possibilities of arranging reports from Farquhar Island, east of Aldabra, gave no indication of a practicable solution. An extra observer was recruited in St Helena and trained at the Meteorological Office College to enable a fuller set of daily observations to be made on St Helena.

Other questions concerning United Kingdom Dependencies included the transfer of the meteorological radio transmission of British Antarctic and Falkland Islands data from Port Stanley to the British Antarctic Survey Base

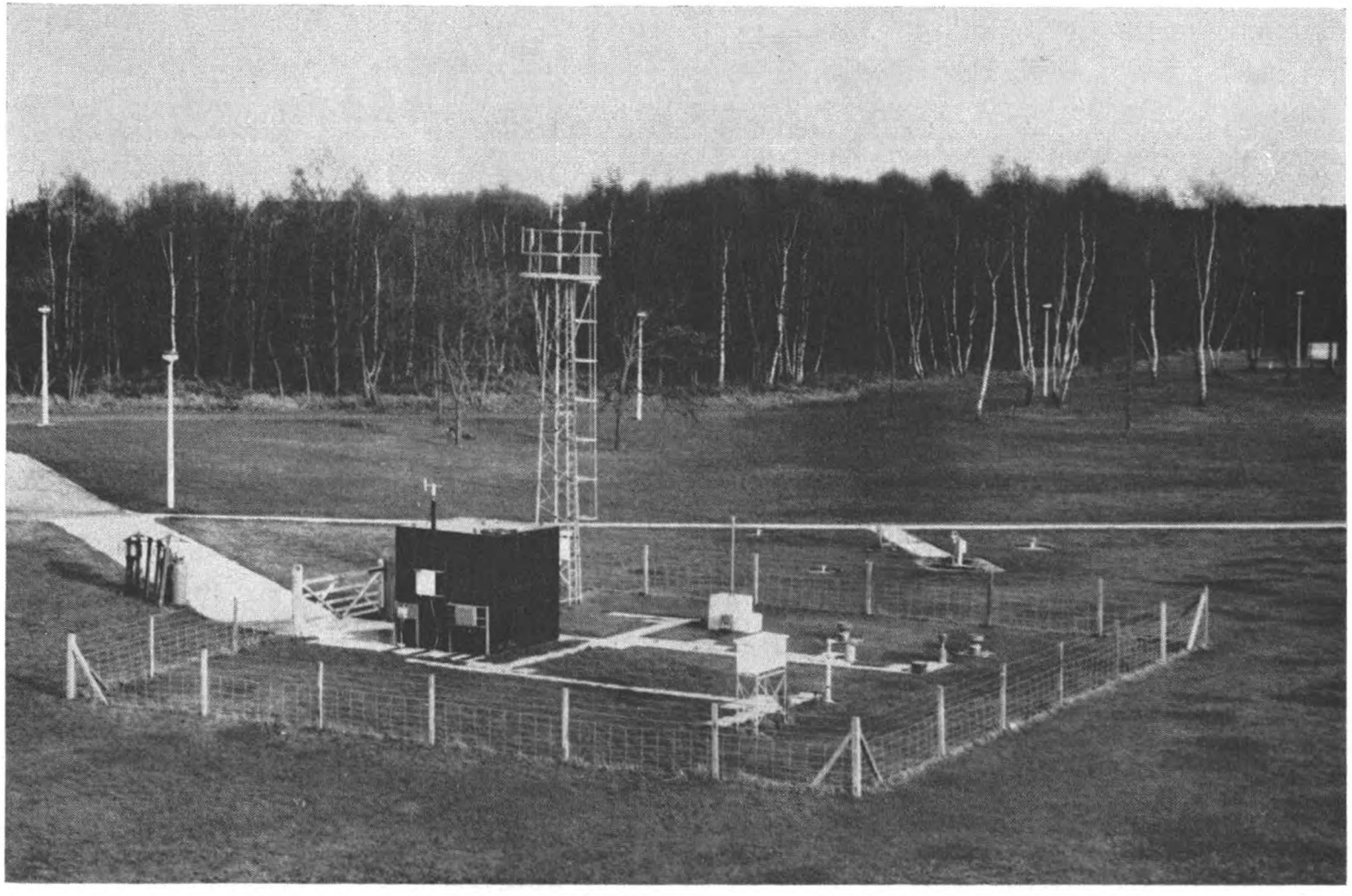
in South Georgia; continued efforts to arrange improved transmission of meteorological reports from St Helena, Ascension, and Seychelles to the desired recipients in Africa; and provision of advice to the Seychelles Government for their representative taking part in the Tropical Cyclone Committee for the South West Indian Ocean. The Directors of the Meteorological Services of Zambia and Mauritius visited the Branch for discussions while they were in England.

Another aspect of World Weather Watch for which the Branch is responsible is technical assistance through WMO's Voluntary Assistance Programme (VAP). The aim is to help other countries implement important elements of the Plan. The financial contribution to the VAP Fund was continued, and practical aid in the form of the provision of equipment and of training fellowships at university level maintained. Details of the fellowships are given in the section on Professional Training. In support of the equipment side of VAP, four Plessey wind-finding radars were despatched by sea in December 1973. The hope was that these stations would be in operation in recipient countries by June 1974 in time for the GARP Atlantic Tropical Experiment (GATE), but for reasons outside our control only one, in Mauritania, was ready in time although not in its permanent location. Another in the Sudan came into operation before the end of the experiment. A radio transmitter for a link with Kano was supplied to Senegal. Offers already made or discussed with several other countries were accepted by them and contract action put in hand; discussions on telecommunication equipment for Iceland were held with the Icelandic Director and the WMO Secretariat. The need for, and possibility of, joint action by several donor countries to meet serious deficiencies in the WWW system in southern Asia and the western Pacific were considered early in the year at a meeting in Singapore. An officer of the Branch took part in this meeting together with representatives of other major donor countries. Lack of reliable information inhibited decisions and hence early action.

The Global Atmospheric Research Programme (GARP) is jointly supported by WMO and the International Council of Scientific Unions (ICSU), and the organizational arrangements are largely carried out through WMO and the Permanent Representatives of Member countries. For GATE there was a high level of such activity through much of the year, the more so because the presence in Bracknell of the International Scientific Management Group for GATE naturally led to close practical relations with the Office. For the First GARP Global Experiment (FGGE) now planned for 1977–79 activity is only now beginning, and the more extensive but less intensive nature of the experiment is leading to a quite different type of organization. A comprehensive list of the United Kingdom's planned WWW activities for the period of FGGE was prepared for use at the first meeting of the FGGE Intergovernmental Panel.

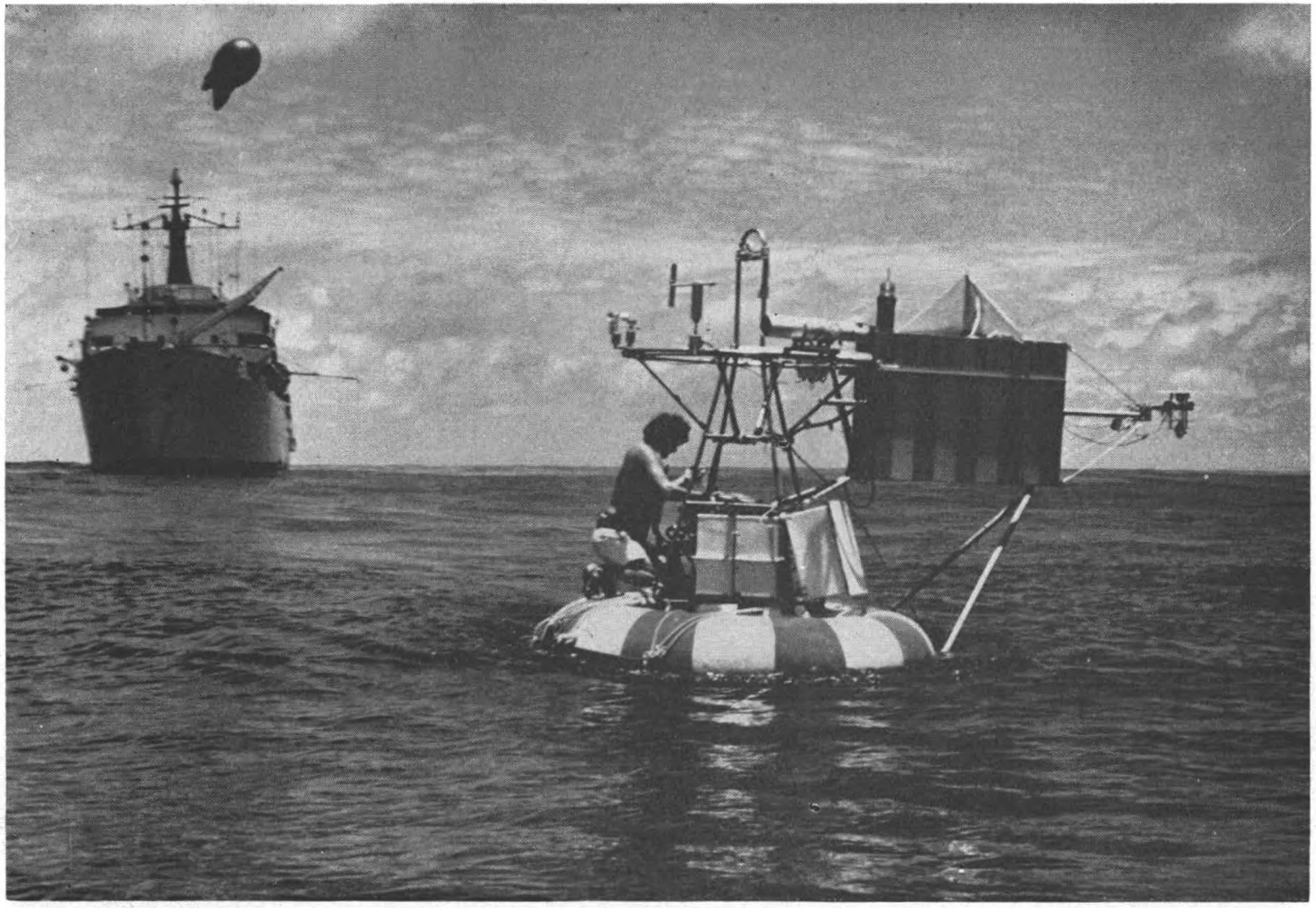
In relation to WMO's Operational Hydrology Programme the Office works together with other appropriate British organizations. After the reconstruction on 1 April 1974 of governmental activities concerned with water resources, Mr O. Gibb, Director of the Central Water Planning Unit of the Department of the Environment, agreed to act as adviser on operational hydrology to the Permanent Representative of the United Kingdom with WMO. Mr Gibb is consulted on hydrological questions arising in WMO work.

The proposed renewal under WMO auspices of the North Atlantic Ocean



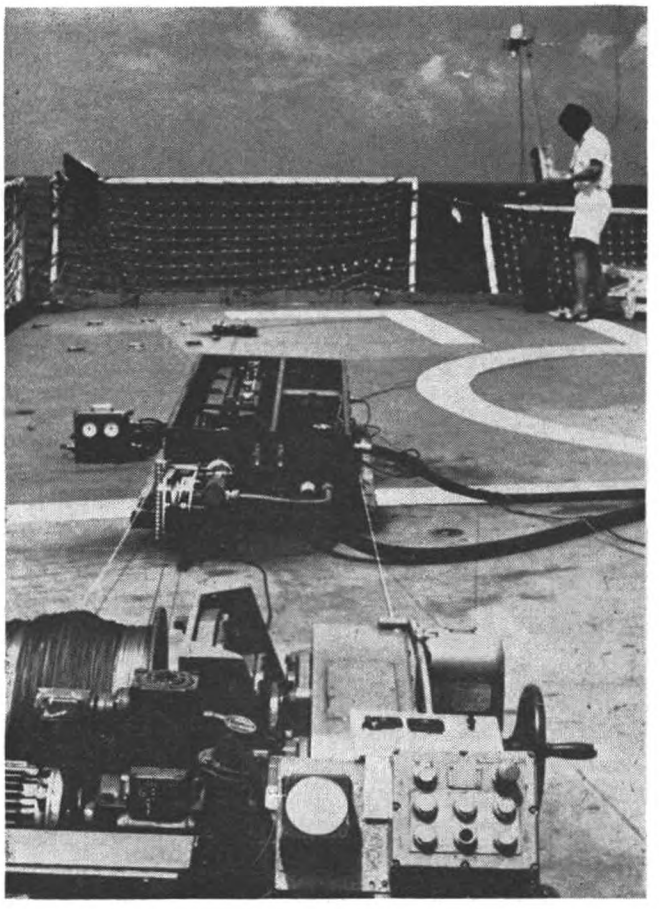
METEOROLOGICAL OFFICE WEATHER OBSERVING SYSTEM MK 2 (MOWOS)

The photograph shows a view, looking east-north-east, of the first MOWOS equipment at Beaufort Park. (See page 6.)



BOUNDARY-LAYER INSTRUMENTS BEING DEPLOYED ON A BUOY DURING THE GARP ATLANTIC TROPICAL EXPERIMENT

(See page 89.)



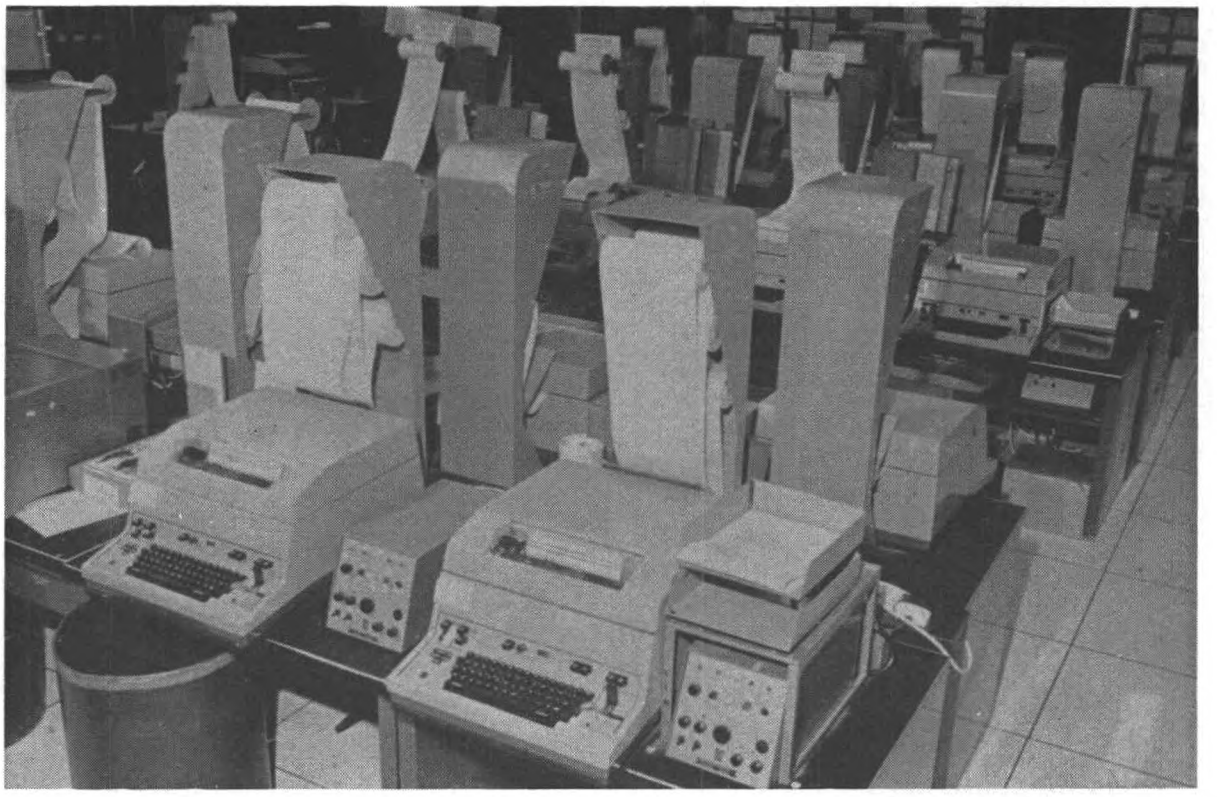
INSTRUMENTS BEING FITTED TO THE CABLE OF THE BALLOON FLYING FROM HMS *Hecla* TO MAKE TURBULENCE MEASUREMENTS DURING THE GARP ATLANTIC TROPICAL EXPERIMENT

(See page 89.)

HERCULES AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT AT DAKAR DURING THE GARP ATLANTIC TROPICAL EXPERIMENT

(See page 89.)

PLATE IV



TELEPRINTER INSTALLATIONS IN THE LOW-SPEED COMPLEX OF THE BRACKNELL TELECOMMUNICATION CENTRE

These conventional Post Office machines operate at 400 characters per minute and are gradually being reduced in numbers as automation progresses. (See page 51.)

HIGH-SPEED LINE PRINTERS ASSOCIATED WITH THE MYRIAD II COMPUTER-CONTROLLED AUTOMATED MESSAGE HANDLING IN THE BRACKNELL RTH

These machines operate at 400 lines per minute. (See page 51.)

Stations scheme, hitherto managed under ICAO arrangements, involved long drawn-out negotiations internationally. As the British ships are the heart of the European operated scheme, negotiations turned largely on the problem of continued financing of their replacement or reconditioning. The geographical extent and scale of support from other countries, mostly in Europe, were important questions. The Plenipotentiary Conference called by WMO in March and again in November agreed to extend the scheme until at least the early 1980s, though on a scale much reduced by the withdrawal of American and Canadian ships.

The recent poor reception of observations from ships in the North Atlantic—especially marked for the 00 GMT observations—coupled with the decrease in weather ship reports, caused much concern to all the meteorological services of western Europe. Many of these reports are collected by British radio stations. A paper on the problems involved was submitted to the September Session of the WMO's Regional Association VI (Europe) which set up an expert working group to make recommendations urgently on what should be done.

A matter of concern to some British shipping was the proposed early introduction of an improved WMO code for reporting ice accretion on ships. It was necessary to ask WMO that its introduction be deferred to give time to amend and distribute to ships' officers publications, logbooks etc., as ambiguity between the new and old codes could affect ships' safety.

The 18th IMO Prize was presented to Mr J. S. Sawyer, Director of Research, by the President of WMO, Mr M. F. Taha, on 17 May. The ceremony took place at the Meteorological Office College in Shinfield Park, and was attended by the Under-Secretary of State (RAF), two former winners of the prize, Professors S. Petterssen and R. C. Sutcliffe, other eminent meteorologists and many friends and colleagues.

Towards the end of the year a party of meteorological and other experts from the People's Republic of China visited the Headquarters of the Office and the office at London/Heathrow Airport. The party was concerned with the development of computer and other automated systems for the Chinese Meteorological Agency. They were shown the main computer system, the telecommunication system and the Central Forecasting Office, and also discussed the Office's observing systems and developments in meteorological instruments.

Further studies of accommodation requirements in Bracknell over the next 10 years were made, as a basis for decisions on building requirements.

J. K. BANNON
Director of Services

STATISTICS OF THE SERVICES DIRECTORATE

The quantitative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I—NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1974

	Within U.K.	Overseas
Principal Forecasting Offices associated with the RAF ...	1	—
Main Meteorological Offices associated with the RAF ...	6	5
Subsidiary offices associated with the RAF	33	8
Observing offices associated with the RAF	7	3
Principal Forecasting Offices associated with civil aviation ...	1	—
Main Meteorological Offices associated with civil aviation ...	3	—
Subsidiary offices associated with civil aviation	11	—
Observing offices associated with civil aviation	7	—
Upper-air observing offices	8	5
Public service offices	6	—
CRDF offices	5	3
Port Meteorological Offices	6	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	3	—
Other offices	27*	3

* Four of these stations are administered by DRMetO

Notes

A Principal Forecasting Office meets the needs of aircraft flying over long distances and operates throughout the 24 hours.

A Main Meteorological Office operates throughout the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

An upper-air observing office may be located with an office of another type if this is convenient.

Public service offices are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II—OCEAN WEATHER SHIPS

To meet its obligation under the ICAO North Atlantic Ocean Station Agreement the United Kingdom operates four Ocean Weather Ships which work in rotation with two ships from France, one ship from the Netherlands and two ships jointly operated by Norway and Sweden. The British ships serve at three of the five ocean weather stations in the eastern North Atlantic; each vessel makes, on average, eight voyages a year and spends an average of 24 days on station during each voyage. Some statistics for 1974 for the British Ocean Weather Ships are shown below.

Total number of days on station ...	654·1
Total number of days on passage ...	149·1

	Station A*	Station I	Station J	Station K†
	average number per voyage			
Aircraft contacted	42	65	156	—
Number of aircraft given one or more radar fixes	26	40	109	—
Weather messages to aircraft	3	4	7	—

* During 1974 Station A was manned by the U.K. for one voyage only.

† During 1974 Station K was operated by France.

TABLE III—MERCHANT NAVY SHIPS

A total of 6928 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization. Most of them, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected ships'; those which report at the same times daily, but in a less complete form, are known as 'supplementary ships'. A number of coasting vessels, lightships, distant-water trawlers and 'auxiliary ships' also make and transmit meteorological observations.

On 31 December 1974 the numbers of British ships reporting were:

Selected ships	538
Supplementary ships	47
	including 16 trawlers
Coasting vessels	50
Lightships	14
Trawlers	6
Auxiliary ships	15
Total	670

The British Voluntary Observing Fleet includes ships of many shipping companies, and the numbers on the various routes are as follows:

U.K. to Australasia	67
U.K. to Far East	85
U.K. to Persian Gulf	34
U.K. to South Africa	52
U.K. to West Indies	31
U.K. to Atlantic coast of North America	74
U.K. to Pacific coast of North America	9
U.K. to South America	23
U.K. to European ports	35
U.K. to Falkland Islands and Antarctica	2
U.K. to distant-water fishing grounds	22
World-wide tramping	130

During two typical days, one in June, the other in November, the number of reports from ships received at Bracknell were as follows:

	Reports *June*	Reports *November*
Direct reception from:		
British ships in eastern North Atlantic	99	102
Foreign ships in eastern North Atlantic	48	46
British ships in North Sea	58	42
Foreign ships in North Sea	2	12
British ships in other waters	2	0
Total	209	202
Reception via other European countries:		
Ships in eastern North Atlantic	415	353
Ships in Mediterranean	52	32
Ships in North Sea	96	151
Ships off northern Russia	26	7
Ships in other waters	136	78
Ships in Pacific	0	2
Total	725	623
Reception via U.S.A. and Canada:		
Ships in North Atlantic	510	377
Ships in North Pacific	890	552
Ships in other waters	216	260
Total	1616	1189

TABLE IV—CLASSIFICATION OF STATIONS RENDERING CLIMATOLOGICAL RETURNS

A large amount of meteorological data is obtained for climatological purposes from stations which are not part of the Meteorological Office organization. The following table shows how the sources of climatological information in the United Kingdom (including Meteorological Office stations) were distributed on 31 December 1974. The areas and titles of the districts in England and Wales are not the same as those listed in the similar table in the *Report* for 1973 as some boundaries have had to be amended in line with the changes of county boundaries in April 1974.

	Stations Supplying Returns					Stations Supplying Autographic Records		
	Observatories	*Synoptic*	*Agrometeorological*	*Climatological*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	10	0	33	315	25	8	16
Scotland, east	0	11	8	62	565	53	22	11
Scotland, west	1	14	1	52	534	28	26	17
England, east and north-east ...	0	10	7	27	596	30	17	13
East Anglia	0	11	13	23	585	32	14	13
Midland Counties	0	14	14	44	1435	52	21	17
England, south-east and central southern (including Greater London)...	1	17	18	46	866	61	27	19
England, south-west	0	14	9	32	631	36	6	9
England, north-west...	0	6	3	23	510	22	11	11
Isle of Man	0	2	0	1	22	3	1	3
Wales, north	0	2	3	17	297	12	3	2
Wales, south	0	10	9	16	415	23	4	6
Channel Islands	0	2	0	4	20	6	0	1
Northern Ireland	0	7	7	47	295	27	45	9
Total	3	130	92	427	7086	410	205	147

* Includes stations in earlier columns.

TABLE V—HEIGHTS REACHED BY UPPER-AIR ASCENTS

The following table shows the number of upper-air ascents giving observations of (a) temperature, pressure and humidity and (b) wind, which have reached specified heights, and the height performance of the largest balloons.

(a) Observations of temperature, pressure and humidity

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K. ...	5824	93·5	76·7	44·3	11·4	54·9
Five stations overseas	3281	96·9	80·7	51·1	7·6	59·8
Four Ocean Weather Ships ...	1534	92·7	72·0	39·8	1·8	—

(b) Observations of wind

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K. ...	11 492	83·6	55·3	24·3	5·6	53·0
Five stations overseas	6 178	90·8	67·1	31·8	4·0	56·3
Four Ocean Weather Ships ...	2 979	83·9	52·2	23·9	1·8	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF Network:

In 1974 ... ... 57 797

TABLE VII—METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchanges of meteorological data which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. The coded messages are composed of groups of five figures and there may be from 5 to around 90 such groups in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic (mainly coded messages and information in pictorial format) through the Meteorological Office Telecommunication Centre, Bracknell, for one typical day (24 hours) taken in November 1974 and, for comparison, some corresponding figures are given for one day near the end of 1973.*

	In	Out	Total	Total in 1973
		number of groups in one day		
Coded messages				
Land-line teleprinter and data transmission	918 906	1 329 580	2 248 486	2 259 098
Radio	219 512	247 978	467 490	442 849
Facsimile charts (pictorial format)				
		number of charts in one day		
Land-line	57	868	925	827
Radio	49	114	163	219

* The very large increase in coded messages to which attention was drawn in last year's *Report* has been sustained because some of the traffic now passing over the MTC continues for the time being to pass over many of the old circuits as well.

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are described in *Met O Leaflet No.* 1 (1972). The numbers receiving such specialized services were as follows:

	Year	No. of customers	Year	No. of customers
Fine-spell notifications (a summer service primarily for farmers) ...	1973	207	1974	186
Week-end temperature forecasts (a winter service primarily for industrialists)	1973–74	27	1974–75	26
Winter road danger warnings (primarily for local authorities)	1973–74	427	1974–75	328

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office acting as a Regional Meteorological Centre of the World Weather Watch is mainly concerned with the analysis of the weather situation and with the issue of forecast charts for the guidance of other offices. The Central Forecasting Office also has a commitment to aviation for the provision of forecast upper-wind and temperature charts for use with the significant weather charts produced by the Principal Forecasting Office at London/Heathrow and the transmission of grid-point data direct to the BOADICEA and APOLLO computers at Heathrow and Prestwick respectively and to the Dutch and Belgian Meteorological Services.

The following figures indicate the numbers of forecasts issued for aviation and the numbers

of meteorological briefings that took place during 1973 and 1974. These do not include warnings and routine general forecasts.

	1973	1974
Number of meteorological briefings for aviation in the U.K.	327 334	350 500
aviation at overseas stations	42 284	44 367
Number of aviation forecasts issued for aviation in the U.K.	1 337 834	1 718 433
aviation at overseas stations	189 876	356 422

TABLE X—NON-AVIATION INQUIRIES

Non-aviation inquiries are handled by five Weather Centres, in London, Manchester, Glasgow, Southampton and Newcastle, and one other office in Nottingham (Watnall) whose function is to meet the needs of the general public for forecasts for special purposes. Many other forecast offices, established primarily to meet the needs of aviation, also answer requests for forecasts and other weather information, from the general public, Press, public corporations, commercial firms, etc. These inquiries, most of which refer to current or future weather, are listed below according to the purpose of the inquiry.

	1973	1974
Total number of non-aviation inquiries	1 745 888	1 854 387
Percentage relating to:		
agriculture	10·5	12·8
building	5·3	5·9
commerce, industry	4·8	5·2
holidays	22·1	22·5
marine matters	14·7	15·8
Press	12·0	10·3
public utilities	9·2	8·9
road transport	9·2	4·5
other known purposes	5·5	5·9
unknown purposes	6·7	8·2

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC for broadcast on radio, and to the BBC and most Independent Television Companies for inclusion in their programmes at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1974.

Area	Dense fog	Heavy rain	Glazed frost and icy roads	Severe inland gales	Winds in coastal waters
Edinburgh and south-east Scotland	—	—	—	5	—
Glasgow and south-west Scotland	1	—	—	5	—
Belfast and Northern Ireland	—	—	—	3	—
Industrial north-east England	—	—	—	3	—
Industrial Lancashire and Merseyside	1	—	1	3	—
Industrial Midlands	1	—	1	3	—
Bristol and Bath	—	2	—	3	—
South Wales	—	4	—	3	2
London and south-east England	—	2	—	2	—
Plymouth and south-west England	1	3	—	2	1
Yorkshire	—	—	—	2	—
Southampton and Portsmouth	—	—	—	3	4
Total	4	11	2	37	7

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

The total number of calls made on the service during 1974 showed an increase of 5 per cent over the previous year.

On 1 April, as an experimental measure, a single forecast for Lancashire, Cheshire, Greater Manchester and Merseyside replaced three separate forecasts for south Lancashire and north Cheshire, the Lancashire coast, and central Lancashire; a forecast for north-east England replaced that for Tyne–Tees; and a forecast for the whole of Devon and Cornwall replaced that for south Devon and east Cornwall.

Information Service Centre	Forecast area	Number of calls 1973	1974
Bedford	40 miles radius of Bedford	197 426	230 551
Belfast	Belfast	228 800	263 197
Birmingham	Birmingham	755 126	780 740
Bishop's Stortford	40 miles radius of Bedford	47 756	70 729
Blackburn	Lancashire, Cheshire, Greater Manchester and Merseyside	264 552	278 739
Blackpool	Lancashire, Cheshire, Greater Manchester and Merseyside	188 646	195 346
Bournemouth	South Hampshire	242 977	334 127
Bradford	Leeds, Bradford, Huddersfield	104 758	117 591
Brighton and Hove	Sussex coast	509 553	548 923
Bristol	Bristol	643 780	533 117
Cardiff	Cardiff	549 603	523 272
Canterbury	Kent coast	213 239	238 092
Chelmsford	Essex coast	106 139	131 932
Cheltenham	South-west Midlands	93 053	104 039
Chester	Chester and North Wales coast	143 571	163 955
Colchester	Essex coast	199 144	200 347
Colwyn Bay	Chester and North Wales coast	82 431	84 007
Coventry	Birmingham	149 972	175 465
Derby	Nottinghamshire, Derbyshire, Leicestershire	159 787	153 081
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	39 358	45 438
Edinburgh	Edinburgh	340 328	347 090
Exeter	Devon and Cornwall	134 931	168 404
Glasgow	Glasgow	577 632	536 530
Gloucester	South-west Midlands	149 741	176 229
Grimsby	North Lincolnshire and Retford area	42 278	50 304
Guildford	London	98 051	116 632
Hereford	South-west Midlands	82 047	90 661
High Wycombe	Thames Valley	70 478	84 528
Huddersfield	Leeds, Bradford, Huddersfield	68 949	72 649
Ipswich	Norfolk and Suffolk	125 147	162 823
Leeds	Leeds, Bradford, Huddersfield	293 234	313 268
Leicester	Nottinghamshire, Derbyshire, Leicestershire	243 626	229 461
Lincoln	North Lincolnshire and Retford area	23 775	65 435
Liverpool	Lancashire, Cheshire, Greater Manchester and Merseyside	351 521	296 582
Liverpool	Chester and North Wales coast	72 947	79 885
London	London	2 897 866	2 872 434
London	Essex coast	144 162	143 914
London	Kent coast	162 145	176 190
London	Sussex coast	295 639	360 625
London	Thames Valley	147 832	151 412
London	40 miles radius of Bedford	82 726	79 468
Luton	40 miles radius of Bedford	120 139	148 393
Manchester	Lancashire, Cheshire, Greater Manchester and Merseyside	502 382	495 834
Manchester	Chester and North Wales coast	74 046	72 252
Medway	Kent coast	129 945	153 720
Middlesbrough	North-east England	151 587	155 969

TABLE XII (*continued*)

Information Service Centre	Forecast area	Number of calls 1973	1974
Newcastle	North-east England	324 176	324 333
Norwich	Norfolk and Suffolk	153 305	215 067
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	535 018	472 917
Oxford	Thames Valley	197 532	199 749
Peterborough	40 miles radius of Bedford	62 205	76 280
Plymouth	Devon and Cornwall	202 847	214 392
Portsmouth	South Hampshire	357 234	481 822
Reading	Thames Valley	251 790	278 139
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	285 482	285 341
Southampton	South Hampshire	392 740	444 636
Southend	Essex coast	148 646	202 944
Southport	Lancashire, Cheshire, Greater Manchester and Merseyside	61 530	53 668
Swindon	Bristol	37 962	43 977
Torquay	Devon and Cornwall	95 032	123 177
Tunbridge Wells	London	92 838	66 110
Total		15 501 162	16 255 932

TABLE XIII—CLIMATOLOGICAL INQUIRIES

Met O 3, Met O 8, Edinburgh and Belfast receive a number of inquiries relating to past weather, to climatology and to the application of meteorological data to agriculture. The following figures give the total number of inquiries and the percentages of this number in various categories.

	1973	1974
Total number of climatological inquiries	17 046	19 561
Percentages relating to		
agriculture (farming, forestry, market gardening)		9·6
building and design (including siting)		20·7
commerce (sales, marketing, advertising)		4·2
drainage		2·2
education and literature		5·2
flooding		0·3
heating and ventilation		2·1
industrial manufacturing activities		3·9
law (damage, accident, insurance)		14·4
medical and health		1·1
Press and information centres		3·1
research		8·1
sport, hobbies, holidays		1·4
transport and communications		1·9
water supplies		9·3
miscellaneous (purpose known)		4·4
miscellaneous (purpose unknown)		8·1

TABLE XIV—DATA PROCESSING

(a) Punched-card installation

Number of cards punched by the Meteorological Office installation	812 826
Number of cards punched elsewhere on behalf of the Meteorological Office	249 079
Number of non-routine investigations completed	28

(b) Processer-controlled keying system

The processer-controlled keying (PCK) system was used for data preparation during 1581 hours.

(c) Computer installation

The IBM 360/195 computer was used for computing during 8575 hours.

TABLE XV—INSTRUMENT TESTING AND CALIBRATION

Numbers of items submitted for testing or calibration including those for outside authorities on repayment.

General meteorological instruments*	56 054
Balloons	44 420
Radiosonde batteries	26 421
Radar reflectors	33 380
Electrical/electronic instruments and systems	878
Electrical/electronic components†	231 394
Radiosondes, Mk 2, calibrated‡	12 644
Radiosonde elements, Mk 3§	13 696
Total	418 887

* Includes calibration of 741 precision aneroid barometers, and certification of 1514 mercury-in-glass thermometers and 167 electrical resistance thermometers.

† Includes quartz crystals, motors and pinions, gearbox assemblies and other Mk 3 radiosonde components.

‡ In addition, 2040 radiosondes were recovered after flight and stripped of re-usable components.

§ Includes temperature and pressure elements.

DIRECTORATE OF RESEARCH

Special Topic—Studies of the Dynamics and Composition of the Stratosphere

Introduction

The rapid expansion in recent years of aerospace technology has demanded from scientists an increased knowledge of the upper atmosphere. Fortunately these demands have been accompanied by a considerable increase in ability to obtain new measurements using aircraft, balloons, rockets and satellites. This has resulted in a great improvement in knowledge of structure, composition and general circulation at high altitudes. It is now known, for example, that the stratosphere, previously thought by some scientists to be a quiet, rather uninteresting region of the atmosphere, is the seat of a number of complex processes, several of which have an important influence on the climate which we experience at the ground. Some of the problems that are now being studied and recent progress in stratospheric research are outlined briefly below.

Principal features

Figure 3 shows mean cross-sections of temperature and ozone concentrations for the northern hemisphere in summer and in winter. On the average the temperature steadily decreases with height in the *troposphere*, the atmospheric layer from the surface to about 9 km in high latitudes and 16 km in the tropics. Above this the rate of decrease becomes small and the temperature then begins to increase with height, reaching a maximum approaching surface values at the *stratopause*, at about 50 km. The *stratosphere* is the region between the troposphere's upper boundary, the *tropopause*, and the stratopause. Stratospheric temperatures vary with latitude, longitude, height and season, the coldest regions being found near the equatorial tropopause and over the winter pole, and the warmest region over the summer pole. Associated with these temperature distributions the tropospheric wind systems rapidly decrease in intensity with height in the lower stratosphere and are replaced at higher levels by rather steady easterlies in summer and disturbed westerlies in winter. Although the annual changes are broadly similar in the two hemispheres, there are some well-marked differences particularly in the winter seasons when the polar regions of the southern-hemisphere stratosphere are considerably colder and the circulation less disturbed than in the northern hemisphere.

One of the major features of the stratosphere is its ozone layer, which has maximum concentration at high latitudes in late winter or spring. Although the ozone amounts are small (in the order of a few parts per million) its presence is of great importance because it strongly absorbs solar radiation in the ultraviolet part of the spectrum between 200 and 300 nm and thus acts as a shield against the penetration of this potentially damaging radiation to the earth's surface. The ozone is formed photochemically and its distribution is determined both by the chemical reactions that take place with other stratospheric constituents and transport by amospheric motions. For instance, many minor or trace constituents derived from particular hydrogen–nitrogen–oxygen–carbon combinations play an important role in determining the ozone distribution, and a

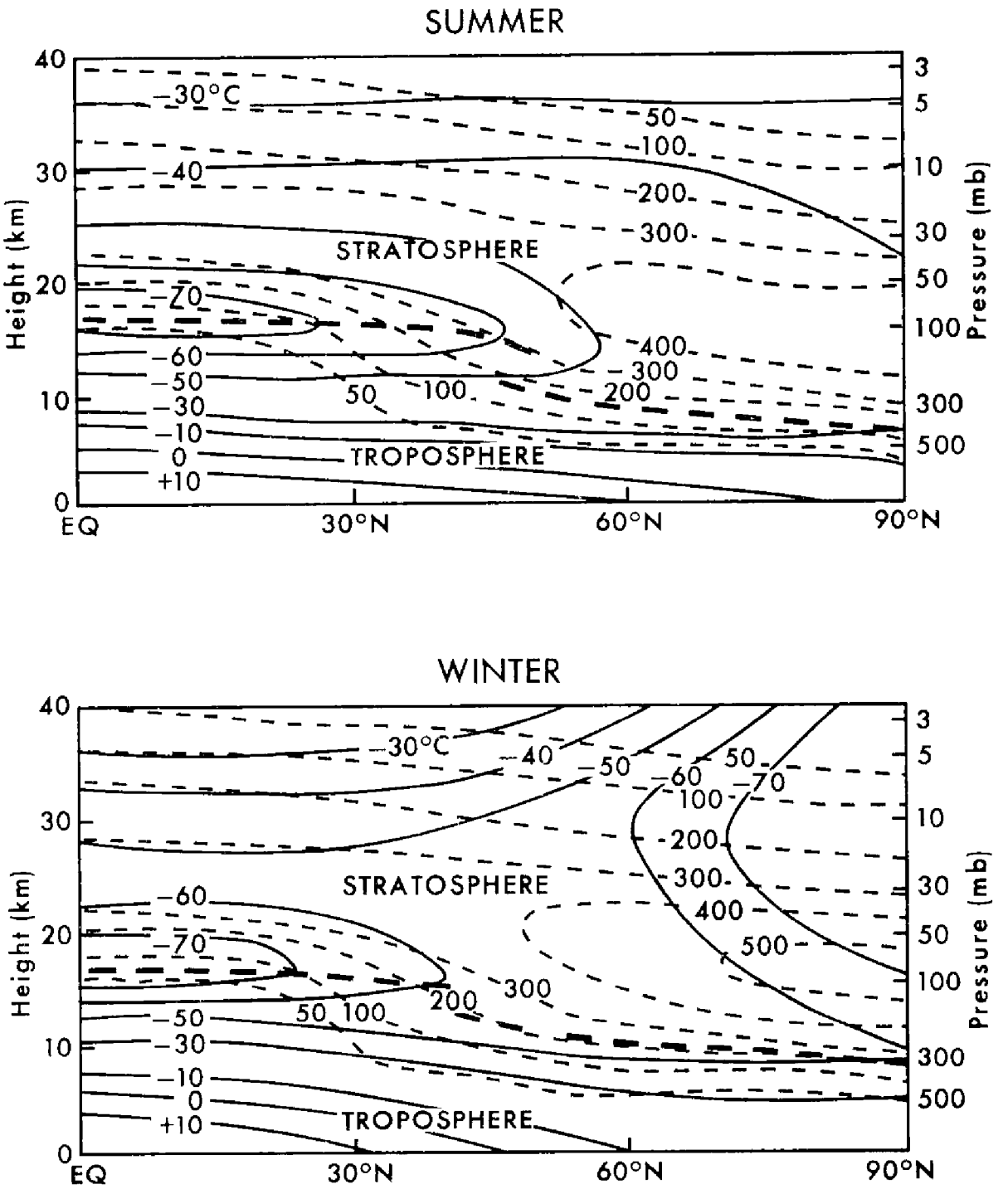


FIGURE 3—SUMMER AND WINTER CROSS-SECTIONS FOR THE NORTHERN HEMISPHERE
——— temperature (°C) - - - - - ozone concentration (μg/m³)
- - - - - tropopause

full study demands a knowledge of all their amounts and distributions. The main source for the hydrogen species (e.g. OH, HO_2 etc.) is water vapour which appears to be supplied from the troposphere mainly through the equatorial-tropopause region and which has only a small mixing ratio of a few parts per million throughout the stratosphere (see Figure 4). Thus the stratosphere is generally very dry and, apart from limited upward penetration of tropospheric clouds into the lower stratosphere, the areas of cloud formation appear to be very limited. (However, there have been suggestions of persistent stratospheric cirrus in winter in the Antarctic.)

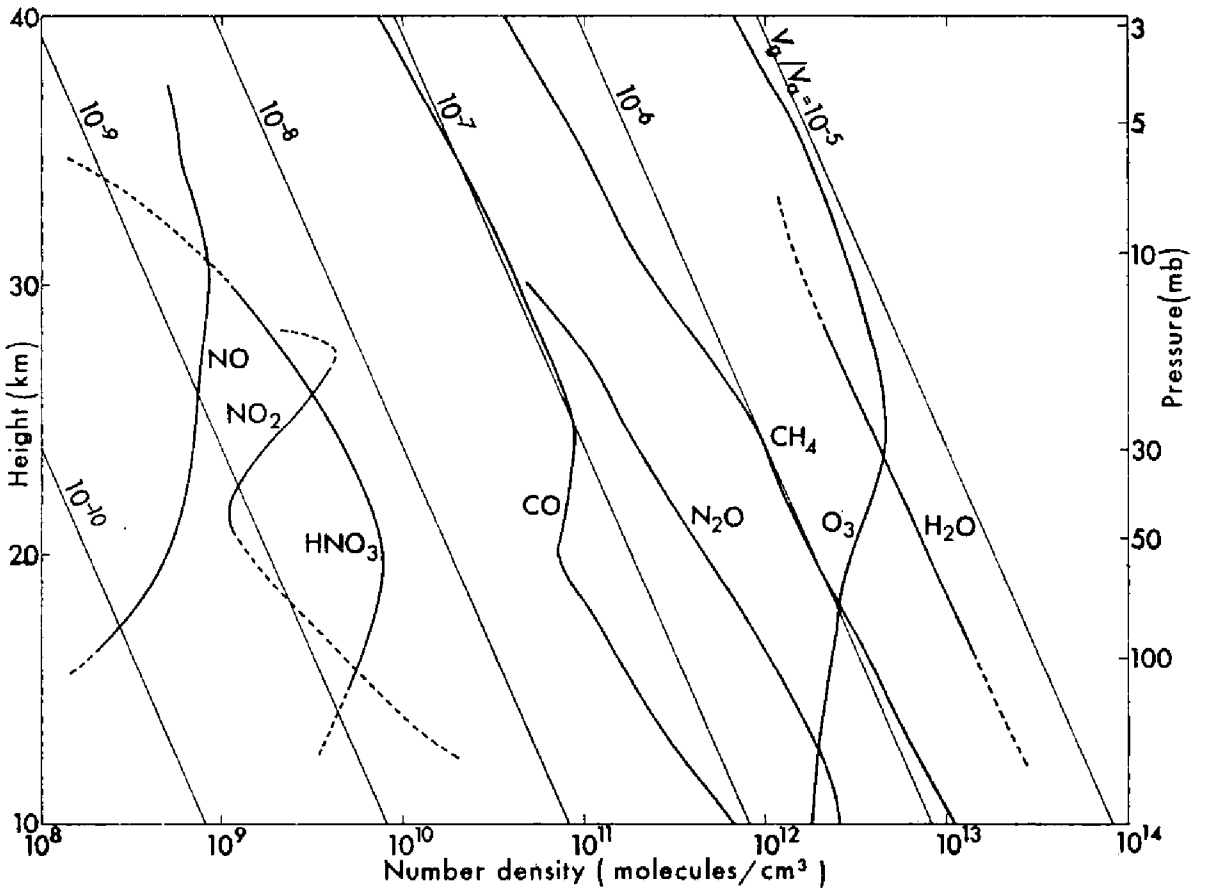


FIGURE 4—A SELECTION OF NUMBER DENSITY PROFILES MEASURED FOR NORTHERN-HEMISPHERE MIDDLE LATITUDES

Scales of volume mixing ratios, V_{gas}/V_{air}, are included. Note the very small mixing ratios of NO, NO_2, and HNO_3 compared with these of H_2O and O_3 (and also with CO_2, for which $V_{gas}/V_{air} \approx 3\times10\text{-}4$).

The principal source of the nitrogen species (NO, NO_2, HNO_3 etc.) is thought to be nitrous oxide (N_2O), biologically produced at the planetary surface, although a contribution from the upper atmosphere of nitric oxide through the stratopause is not ruled out. The carbon species, in addition to carbon dioxide, include carbon monoxide, methane etc. and these and the sulphur species, such as sulphur dioxide, are also thought to be supplied from the lower atmosphere. The principal problem in understanding the natural composition of the stratosphere is to assign the correct importance to all the possible chemical and physical processes which determine the distributions as far as they can be measured at present. This requires a full consideration of the penetration of solar radiation, possible chemical reactions, transport by atmospheric motions and likely source and sink mechanisms of the different constituents, including transfer processes between stratosphere and troposphere and also with the atmosphere above.

The first explanation for the mean temperature profiles of the troposphere and the stratosphere put forward by Gold, Emden and others in the early part of the century was that the troposphere, bounded at the bottom by the earth's surface, has a temperature distribution controlled primarily by convection, while that of the stratosphere above is controlled primarily by radiation. Although both dynamical and radiative effects are important in each of the

regions, this theory accounts for most of the major features. The temperature maximum near the stratopause is mainly due to direct absorption of solar radiation by the upper parts of the ozone layer. Further absorption by ozone in the ultra-violet and visible parts of the spectrum and by other minor constituents, such as water vapour and carbon dioxide, in the near infra-red regions of the solar spectrum takes place in the lower parts of the stratosphere. The radiatively important constituents providing the balancing infra-red atmospheric emission are also carbon dioxide, ozone and water vapour. The net effect of these radiative processes is to produce a small heat source near the equatorial tropopause and a larger heat source at high latitudes in the summer hemisphere near the stratopause, with a heat sink at high latitudes in winter.

The distribution of these heat sources and sinks, together with the forcing effect of the tropospheric circulations on the lower stratosphere, determine the main features of the temperature distribution and the general circulation of this region. The motions redistribute the stratospheric constituents and hence react on the radiation field so that the stratosphere is a very interactive system which can only be understood by considering all these processes simultaneously. In addition to questions arising from its mean structure, the stratosphere has many other features arising from its observed variability that require explanation. For example, the winter circulation occasionally departs markedly from the condition of strong westerly winds blowing round a cold polar vortex. A warm centre may rapidly move over the pole from lower latitudes, developing and intensifying as it does so, causing within a few days local temperature rises of some tens of degrees Celsius ('sudden warmings'). When this occurs an anticyclonic region may build up over the poles in the stratosphere and its main wind systems will become easterly (see Figure 5). Another major feature is the so-called 'quasi-biennial oscillation', first associated with reversals of the mean zonal stratospheric wind at low latitudes from easterly to westerly with a period of two to three years. In addition, detailed analyses of upper-air data in the tropics have also revealed the presence of other oscillations, e.g. a semi-annual oscillation, atmospheric Kelvin waves and other long-period waves. Observations indicate that the total global ozone amount in the stratosphere varies irregularly from year to year and long-period changes also appear to take place.

Some research problems

In addition to the general requirement of studying as much of the atmosphere as possible to advance meteorological science and establish a basic background knowledge, there are many other reasons why the study of the stratosphere has increased in importance in recent years. It has long been recognized that studies of climate and weather forecasting, particularly those involving the use of numerical models, require a good specification of the troposphere's upper boundary conditions. The nature of the stratosphere also influences the penetration of solar radiation to the lower atmosphere and the fluxes of atmospheric radiation. In this and other connections, the stratosphere provides the vital link between possible changes in the upper atmosphere due to solar and other effects, and any climatic changes that might result in the lower atmosphere. As regards day-to-day practical problems, since jet aircraft, both military and commercial, now fly regularly in the lower stratosphere, it is necessary to

have the capability of forecasting as a routine the winds, temperatures, turbulence etc. expected there, in addition to acquiring all the special information concerning means, variability and extremes of the different meteorological parameters needed for aeronautical design purposes.

Most of the above requirements are primarily concerned with the temperature structure and general circulation of the stratosphere and present no basically new problems to meteorologists. Other questions, such as the residence period in the stratosphere of the products of nuclear explosion experiments in the 1950s and 1960s and their rate of descent to the earth's surface, emphasized the need for an improved understanding of transport mechanisms, horizontally within the stratosphere and vertically between stratosphere and troposphere. In the last few years new questions have been raised regarding the possible effects of 'stratospheric pollution' as a result of the large-scale operation of aircraft, particularly supersonic transports in the stratosphere, and these have raised some very difficult problems. It has been suggested that the continuous injection along air routes of the exhaust gases (mainly carbon dioxide, water vapour, carbon monoxide, nitrogen oxides, sulphur dioxide and hydrocarbons) will ultimately lead to important changes in stratospheric composition, and this in turn will produce significant changes in the human environment. Since tropospheric cloud and rain systems do not extend up to the stratosphere these contaminants have to be transported across the tropopause from above before being washed out. Moreover, except at high latitudes in winter, vertical transport processes and mixing are slow in the stable conditions of the stratosphere. It is known from the nuclear debris and other studies that concentrations of injected material may take as long as a few years to decrease by 50 per cent, as a result of vertical transfer to the troposphere, and that this stratospheric residence time increases considerably with the height above the tropopause. The comparable average time in the troposphere is of the order of weeks. Accordingly, depending on the amounts and levels of the injections in the stratosphere and the relative rates of the chemical reactions between the injected gases and the natural constituents, some changes may be anticipated in the composition of the stratosphere. These changes in turn will have some effect on the penetration of solar radiation through the stratosphere and also on the radiative heating and hence will perturb the stratospheric general circulation. There may then be some changes in the circulation of the atmosphere below, causing some climatic effects.

As regards the relative importance of the different perturbations caused by aircraft injections, a direct comparison of the rate of emission of the different exhaust gases with the natural sources of the different constituents shows that the nitrogen oxide content is likely to suffer the greatest changes. In contrast the carbon dioxide and water vapour injections, which are much greater, are only likely to produce smaller relative increases in their natural concentrations. Photochemical studies indicate that the ozone amounts are sensitive to the nitrogen oxide concentration and will decrease as the latter increases. The magnitude of this possible effect is in doubt but, if it occurred, some increase in the penetration of solar ultra-violet radiation around 300-nm wavelength would follow. Hence it is necessary to construct a chemical kinetics model of the natural stratosphere which is also capable of indicating the significance of any perturbations of this type that might result from the anticipated injections. It is, of course, essential to check the model predictions as

far as possible, and to seek corroborative evidence. One suggested check was to estimate the nitrogen oxides produced in the stratosphere during the large-scale nuclear test series of the 1950s and 1960s and look for any possible effects on the measured total amounts of ozone in the atmosphere during this period. The injected nitrogen oxide amounts estimated independently by several authors are in general agreement and are broadly equivalent to the anticipated emissions in the stratosphere from large fleets of supersonic transports in this period. However, it has not been possible to discern unambiguously any corresponding changes in the total ozone amounts (see Goldsmith *et alii*[1]). The record of total global amounts, which is based on a summation of those measured at a selection of stations over the world, shows considerable variability from year to year and this has not yet been explained. One of its more puzzling features is a general rise in total ozone in the 1960s in the northern hemisphere. There is evidence also of a rise in stratospheric water content in this period.

The second largest potential effect appears likely to be due to the amount of sulphur dioxide which is present in the exhaust emissions on account of sulphur compounds in the fuel. The sulphur dioxide may form sulphate particles, resulting in increased aerosol content of the stratosphere which, by absorbing solar radiation at different wavelengths, may cause increased heating in the stratosphere, circulation changes and possibly some climatic effects. In many ways the quantitative assessment of the processes involved in this sequence is more difficult than that of estimating possible changes in the penetration of the solar ultra-violet radiation. At present little is known of the aerosol chemistry, the size spectra and the scattering and absorption processes which may take place. Even if the heating rates are estimated realistically there still remains the problem of estimating the changes in the lower atmosphere which will follow the stratospheric perturbations. Solution of the problem only seems possible by constructing a full numerical global model of all the atmospheric processes involved. The only external evidence on this question comes from climatological records in the periods following other large-scale perturbations of the stratosphere. For example it is known that the Bali volcanic eruption of 1963 injected large amounts of dust into the stratosphere. These were associated with rises of stratospheric temperatures of a few degrees Celsius but the accompanying changes in surface temperatures appear to have been only a fraction of a degree Celsius and statistically insignificant.

A final possible effect is that the emission of water vapour from the engine exhausts may produce persistent condensation trails in the low-temperature regions of the stratosphere near the equatorial tropopause and over the poles in winter, particularly in the southern hemisphere. However, the likelihood of the formation of persistent trails by supersonic transport aircraft flying in the dry stratosphere is thought to be small compared with that of subsonic aircraft flying in the more humid regions of the upper troposphere.

It is clear that realistic quantitative assessments of the possible significance of the effects discussed above, in terms of the anticipated amounts and heights of the aircraft emissions, need a full understanding of all the processes that determine the state of the natural stratosphere, and an ability to predict with confidence the effect on the atmosphere of these types of perturbations. This represents a formidable challenge to meteorological science since it requires

major advances in knowledge of the stratosphere and its relations with processes in the lower atmosphere. At the request of the Concorde Division, Department of Industry, the Meteorological Office has undertaken a short-term research programme to study these problems and provide background information to make the best possible assessments in the light of modern knowledge. Similar work is being carried out in other countries, notably the U.S.A. and France, with whom there is close co-operation and some of the progress and background studies, up to date, will be discussed briefly below.

Recent progress in stratospheric research

It has become evident in the last two decades that Chapman's theory, put forward in 1930, that the distribution of ozone in the stratosphere is determined photochemically by reactions between the oxygen species O, O_2 and O_3, is not able to explain completely the observed distributions. Although photochemical theory predicts the largest concentration of ozone at low latitudes, where the solar beam is nearest to the vertical, the observed values are largest at high latitudes. This is due to horizontal and vertical transport by the air motions. However, even taking this into account, discrepancies remain and it is now accepted that the photochemical theory must be generalized to explain the distributions of all the stratospheric constituents in an oxygen–hydrogen–nitrogen–carbon–chlorine atmosphere irradiated by the sun. It is now common to read in the literature of chemical schemes involving the so-called HO_x (OH + HO_2 etc.) and NO_x (NO + NO_2) species, as well as many other substances, such as HNO_2, HNO_3, CH_4 and others containing chlorine, all contributing to the final state of the stratosphere. The most recent appraisal made in the Meteorological Office suggests that some 40 species and 100 reactions have to be considered. A quantitative study of stratospheric composition, including the importance of the different processes involved, requires a mathematical model with a chemical kinetics scheme which takes all these reactions into account, and this is now in use. To be even partially successful it is necessary to have suitable data on the solar spectrum, all the necessary chemical reaction rates, the basic sources, sinks and distributions of the different constituents, and the transports involved. Some of these data are available but it is necessary, in particular, to know a great deal more about the amounts of the constituents at different levels. Many of these are difficult to measure, particularly those of the NO_x family which have mixing ratios of the order of 10^{-9} or less. A great deal of progress in obtaining new measurements has recently been made in this country by scientists in the Division of Electrical Sciences, National Physical Laboratory[2] and the Atmospheric Physics Department, University of Oxford, working in conjunction with the Meteorological Office, and also by scientists abroad working on similar projects in the French and American programmes. Figure 4 shows a selection of profiles of stratospheric constituents; some of the results are still tentative as they have been obtained with new techniques only in the last few years. Data on stratospheric aerosol distribution have also increased considerably and an experimental apparatus to measure heating in the stratosphere due to aerosols is being constructed in the Meteorological Office for use on a balloon. Similarly there has been a great expansion recently in the amount of data on chemical reaction rates, from laboratory studies made in this country on behalf of the Meteorological Office,

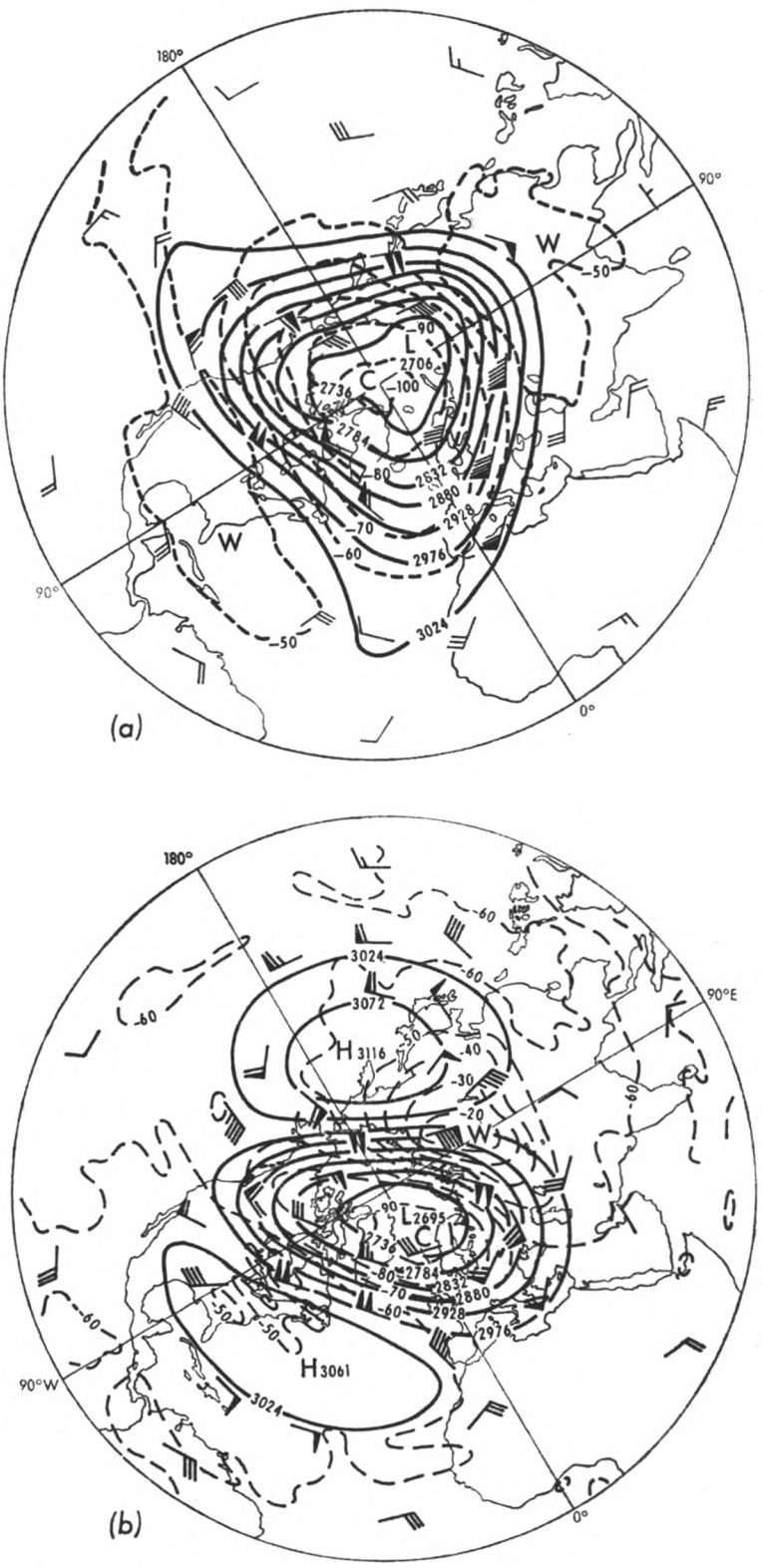


FIGURE 5—THE EVOLUTION OF A 'SUDDEN WARMING' AT THE 10-mb (30-km) LEVEL IN THE THREE-DIMENSIONAL MODEL'S SIMULATION OF THE NORTHERN HEMISPHERE

———— contour heights (geopotential decametres). – – – – – temperature (°C). Wind arrows are shown, each barb representing 10 m/s. Centres shown are H (contour high), L (contour low), W (warm) and C (cold).

(a) The pre-warming situation dominated by the cold polar vortex in winter (72nd day in the integration)

(b) The development of anticyclonic highs and the movement of a warm centre towards the pole (82nd day)

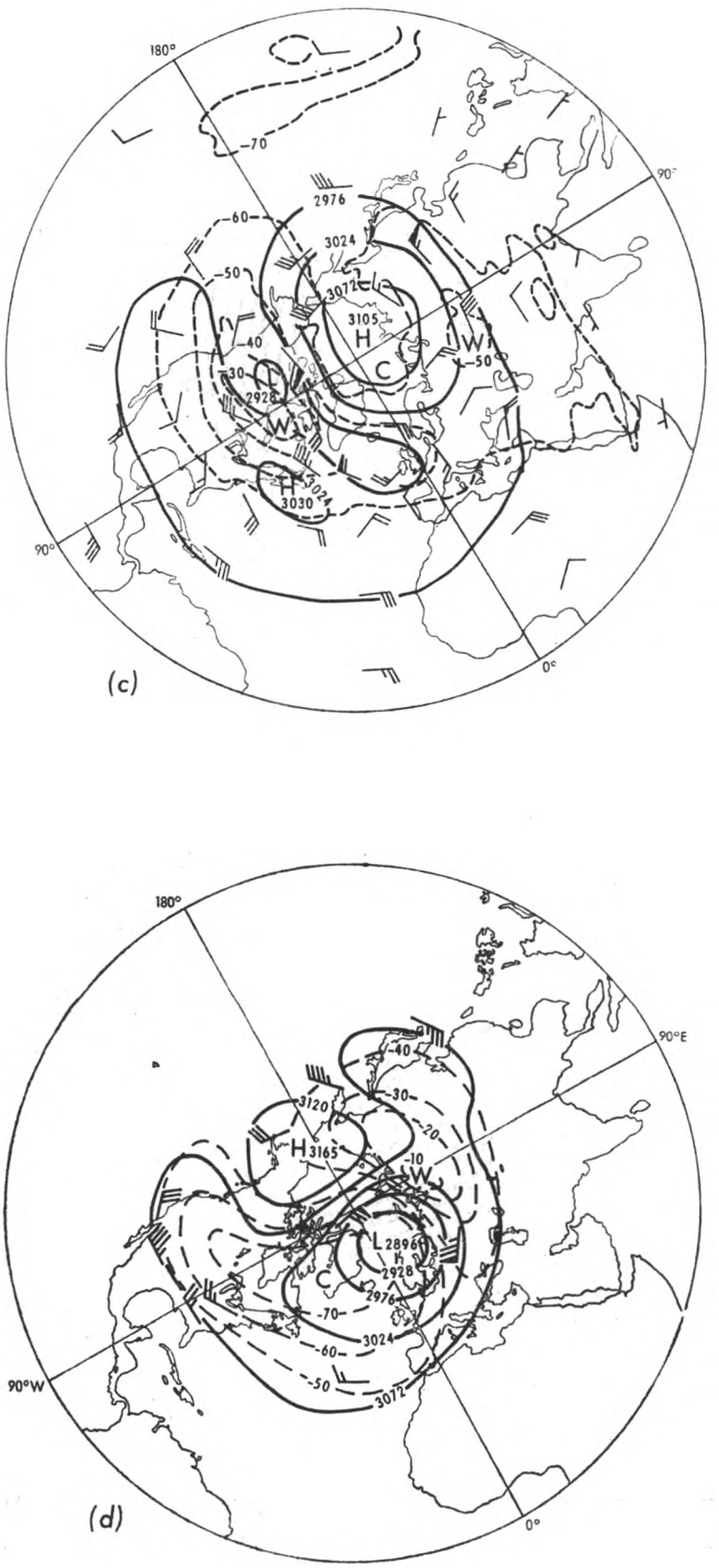


FIGURE 5—*continued*

(c) The vortex is weakened and displaced to lower latitudes and a high with its easterly circulation is dominant over the pole (100th day)

(d) The observed 10-mb situation on 1 January 1970 during an actual stratospheric warming.

by the Physical Chemistry Departments of the Universities of Oxford and Cambridge, and also from the major efforts on this work made abroad, particularly in the U.S.A.

Studies of the mechanisms involved in transferring the different constituents throughout the stratosphere and to the lower atmosphere require a full three-dimensional model of the troposphere and stratosphere properly to account for the effects of atmospheric motions. The Meteorological Office has developed several large numerical models of the general circulation in the troposphere during the last few years and extensions have now been made to produce a 13-level global model extending from the surface to about 44 km. This troposphere–stratosphere model contains all the features associated with the previous modelling, i.e. a hydrological cycle, boundary-layer transfers, topography, tropospheric convection and a radiation scheme and, in addition, the main stratospheric features, including an ozone layer. Simulations of tropospheric structure, the tropopause and the main synoptic and other features of the stratosphere are reasonably realistic. In addition it has proved possible to simulate many of the properties associated with 'sudden-warming' phenomena. Figures 5(a)–(c) show a sequence of 10-mb charts spanning a 'warming' simulated by the model. Figure 5(d) shows for comparison a similar chart, constructed by the High Atmosphere Branch in the Meteorological Office of an observed 'sudden warming'. The studies of the simulated stratospheric dynamics and energetics within the model will, it is hoped, lead to a wider understanding of the natural processes that take place. In addition movements of ozone and other tracers within the stratosphere can be readily followed within the model's simulated circulation as can also the spread of injected material.

If the representation of the natural troposphere and stratosphere is sufficiently realistic, the possibility exists of using this model to study the effects of perturbations of the concentrations of the different constituents. A number of experiments are being made with different amounts of ozone and water vapour and with the addition of extra radiative heating that could arise from varying the aerosol layer in the stratosphere to investigate the magnitudes of the changes that result in stratospheric temperatures and the general circulation. At the same time, effects are observed in the lower atmosphere's behaviour within the model and attempts are being made to assess the significance of the accompanying changes in surface temperature and rainfall. The results, to date, show that even if large changes are introduced in the stratospheric conditions, the consequent changes in the lower atmosphere are small, and it is very difficult to ascribe them unambiguously to the disturbances at the higher level. Moreover the photochemical calculations, at their present stage, appear to confirm the experimental evidence that the effect on ozone of NO_x injected by nuclear bomb tests in the 1950s and 1960s (or by any possible fleet of supersonic aircraft in the next decades) would be well within the range of natural ozone fluctuations.

Although considerable progress has been made, a great deal of effort will be necessary before an understanding of the composition, temperature structure and general circulation of the stratosphere is likely to be sufficient to pronounce with confidence on the quantitative effects that might follow from disturbance of the stratospheric composition. Many more measurements of stratospheric constituents including their distribution in time and space are needed. Further studies of the basic photochemical processes are also required. In the atmospheric

modelling procedures, improvements are urgently needed in the treatment of features such as the effects of clouds on the radiative heat balance and the simulation of the small sub-grid-scale contributions, and it will ultimately be necessary, in studies of climatic changes, to include atmosphere–ocean interactions. In the upper atmosphere the requirement is for a model which is fully interactive between composition, radiation, temperature and general circulation effects, and it is now possible with sufficient effort and computer facilities to extend this work well above the stratosphere.

REFERENCES

1. GOLDSMITH, P., TUCK, A. F., FOOT, J. S., SIMMONS, E. L. and NEWSON, R. L.; Nitrogen oxides, nuclear weapon testing, Concorde and stratospheric ozone. *Nature, London*, **244**, 1973, pp. 545–551.

2. HARRIES, J. E., MOSS, D. G. and SWANN, N. R.; H_2O, O_3, N_2O and HNO_3 in the arctic stratosphere. *Nature, London*, **250**, 1974, pp. 475–476.

PHYSICAL RESEARCH

Cloud microphysics

During the past few years further significant insights have been gained into the detailed roles of condensation, coalescence and ice crystals in the growth of precipitation, as the result of both theoretical and laboratory studies in the Cloud Physics Branch.

Last year, calculations were carried out on droplet growth from the initial condensation including later simulated coalescence of the droplets, in which one cloud-producing updraught was considered to be rising through and mixing with the decaying remains of a previous updraught. This mixing mechanism was found to account for the spread in the sizes of cloud droplets observed in nature. The model is now being extended to include the effect of radiative heat transfer between individual droplets and their environment, and more detailed description of the characteristics of the particles on which the cloud droplets initially condense. Preliminary results suggest that the inclusion of the radiational cooling produces small but significant effects on the droplet growth.

In temperate and high latitudes, most precipitating clouds extend to heights where the temperature is below 0°C. Under these circumstances, it has long been known that the ice phase has a strong influence on the development of precipitation. This is because pure water in the form of small droplets does not freeze until it reaches temperatures as low as −35°C to −40°C depending upon droplet size. Thus clouds at temperatures somewhat below 0°C are composed predominantly of supercooled water droplets. However, there are some small particles in the atmosphere which can initiate freezing at much higher temperatures than those required for spontaneous ice nucleation. A few ice crystals produced in this way in supercooled clouds provide centres of growth for precipitation-sized particles because the differences in water vapour pressure over water and ice results in water vapour being transferred from the water droplets to the ice particle by diffusion. Once the ice particle is large enough to fall relative to the water droplets it will grow further by collision and coalescence with them.

In view of the role played by ice crystals the factors which control the ice budget in clouds continue to be studied. Experiments are under way to try to account for the fact that in some types of cloud the number of ice crystals

greatly exceeds the number of particles capable of initiating freezing. Recent experimental results reported from Australia showed a great increase in ice-crystal multiplication during riming in the presence of a wide size-range of supercooled droplets in a narrow range of temperatures near −5°C. This work is being repeated and extended in the hope of increasing understanding of the detailed physics involved.

It has been well established that silver iodide particles will initiate glaciation in supercooled clouds at temperatures much higher than that at which they would naturally glaciate, but the precise mechanism of the nucleation is not understood. Laboratory experiments, in a specially designed cloud chamber, now suggest that for sub-micron-sized silver iodide particles direct growth by water-vapour diffusion (sorption freezing) is more important than physical contact between the silver iodide particles and the small supercooled droplets in the chamber. The effectiveness of the silver iodide particles as sorption nuclei at water saturation is enhanced when they are allowed to coagulate with natural aerosol or with artificially produced sodium chloride particles. However, silver iodide particles exposed to large supersaturations and so acting as condensation-followed-by-freezing nuclei are very much more effective than they are for sorption nucleation.

These theoretical and laboratory investigations provide an extensive background for the formulation of well-defined field studies of the droplet and ice-particle populations of clouds.

To this end, special instrumentation for measuring the microphysical characteristics of clouds continued to be developed and tested. A considerable effort has been devoted to designing a holographic laser system with sufficient resolution to allow three-dimensional reproductions of cloud samples to be set up in the laboratory. This system has now been finalized and a method for automatically analysing the vast amount of data that will be forthcoming from this type of sampler shows great promise.

The measurement of the electrical properties of clouds, using instrumentation installed in the Varsity aircraft of the Meteorological Research Flight, has continued. Preliminary results are not inconsistent with a dependence of field strength in cloud on the onset of glaciation.

Dynamics of precipitation systems

A mathematical representation of cumulonimbus in three dimensions, originally developed by M. J. Miller, Department of Meteorology, Imperial College, to simulate tropical convection, has been adapted to study the development of cumulonimbus in temperate climates. It has become clear that the way in which convection develops depends crucially on whether it is initiated by sudden or by gradual changes in the boundary layer. After further exploration of this factor, it is planned to introduce glaciation into the model as one of the tools needed to further understanding of the importance of the glaciation process in precipitation growth and the dynamics of such clouds.

Analysis of the data obtained in Project Scillonia, the project designed to study the dynamical structure of fronts in relation to the mesoscale distribution of precipitation, has been completed and results are in course of publication. We now have a reasonably complete picture of the distribution of precipitation and field of motion, including vertical motion, in a 'box' about 300 km × 100 km × 4 km ahead of one warm front, and less-complete information for two

other occasions. There appears to be an association between the mesoscale motion and a banded structure in the rain (of characteristic spacing 100 km). These results provide a firm observational framework within which to develop and test numerical models of fronts. A computational scheme for a numerical model of frontal development which includes the effect of latent-heat release in ascending air is being formulated in collaboration with Dr Hoskins, Department of Geophysics, Reading University.

The frontal structure observed during Project Scillonia has also been compared with an earlier numerical model of frontogenesis by Hoskins, and found to show some marked similarities (the formation of a low-level jet running parallel to, and ahead of, the surface warm front) and dissimilarities (due mainly to the superposition of the circulation associated with an approaching cold-front occlusion). This has given further insight into the interaction of frontogenesis with the distribution of precipitation.

It is planned that future field-studies will include measurements of the mesoscale distribution of temperature and humidity in addition to wind. For this purpose a dropsonde has been designed for continued studies of the mesoscale dynamics of weather systems and has reached the definition prototype stage. Altitude is measured to $\pm$1–2-mb r.m.s. error; air temperature to $\pm$0·2 degC with a time constant of 2–3 seconds by using a low thermal capacity thermistor, and relative humidity to $\pm$5 per cent in the range 95 to 20 per cent by using a carbon hygristor. Winds will be defined to $\pm$0·3 m/s over a height interval of 500 m by using radio-navigational aids to monitor the position during fall. Up to 5 dropsondes may be tracked at any one time with all the necessary tracking and recording equipment being housed in the Meteorological Research Flight's new C-130 aircraft. After an extensive series of trials, the sonde has been given safety clearance for use with this aircraft. A preliminary limited pilot exercise with this equipment is planned for the late summer of 1975.

Fog studies

The first phase of the study of the basic physics of radiation fog has been completed. This consisted of a field-study (based at Cardington) in parallel with a numerical study. Both studies point to the major factors which control the evolution of radiation fog as being radiative cooling, turbulent diffusion, gravitational settling and soil heat-flux. These factors all interact in a complex manner which clearly involves the microphysics of fog, particularly in the vicinity of the fog top.

The second phase of the project will concentrate on a study of the interaction of radiation and the fog droplet characteristics. It is planned to make simultaneous measurements of the profiles of wind, temperature, radiative flux and drop-size distribution, by using specially built instrumentation attached to a tethered balloon which will allow the sensors to be raised and lowered through the fog top.

Radar meteorology

The main emphasis during the past year has been on the use of weather radar at three sites (Defford, Llandegla and the Gower Peninsula) in the study of the influence of orography on the distribution of precipitation. This distribution has been found to be considerably influenced by the behaviour

of the air at low levels in the warm sector, where there is often a maximum of wind speed a few hundred metres above the ground, the 'low-level jet'. Precipitation usually originates at higher levels but the amount reaching the ground depends on how much water is swept up in falling through the low-level clouds. Thus when the low-level jet is forced up by hills, and its liquid water content increased, there is often a considerable enhancement of precipitation. The warm-sector low-level jet subsequently ascends over the cold air ahead of the surface warm front and the amount of precipitation released will clearly be affected by earlier orographic depletion of water content. Possible connections between the orographic effects and the observed organization of frontal precipitation into rain bands are being studied.

The radars used in this project will form the basis of an interlinked research network which will transmit digitized rainfall-intensity data along Post Office lines to a central processing point. These data will be used to study the mesoscale structure of precipitation systems, and will be presented in an easily assimilated form on a colour television tube. A preliminary demonstration of this system in the Central Forecasting Office aroused considerable interest for its potential in short-term forecasting for the general public and for the management of water resources. Some problems concerned with the distortion of the intensity display by the melting band remain.

Radar studies of the structure of the boundary layer using clear-air returns have continued. This year, a study of the diurnal development of the depth of the convective boundary layer was made with the Defford radar, in collaboration with the Appleton Laboratory radar at Chilbolton, as part of the 1974 Co-operative Atmospheric Boundary Layer Experiment (CABLE 74). Analysis is in progress.

Improvement of the Malvern radar facilities has continued with the upgrading of the power and range resolution of the high-power Doppler radar at Defford. The construction of an X-band FM/CW radar is being carried out jointly by the Royal Radar Establishment (RRE), Malvern and Birmingham University.

Air pollution studies

As part of the World Meteorological Organization (WMO) network, a background pollution monitoring station has been established at Lerwick to measure contamination in the air and in rain water. Subsidiary stations have also been set up to test the representativity of rain chemistry measurements. They have shown that important differences can occur between different locations and different types of sampling equipment on the same site at coastal locations.

A balloon-borne system for measuring the absorption of solar radiation by aerosol in the stratosphere (by detecting sound produced by the absorption of heat from a chopped solar beam) is nearing completion. Successful tests of some components of the equipment have been made at Cardington, and it is hoped that the assembled system will be ready for a flight using the French Balloon Facility early in 1975.

The atmospheric boundary layer

Two major experimental studies have taken place in 1974, relevant to a better understanding of processes within the atmospheric boundary layer.

(The 'lowest kilometre of the atmosphere' was discussed in detail in last year's *Annual Report.*) As discussed in greater detail elsewhere in this report, the Global Atmospheric Research Programme (GARP) Atlantic Tropical Experiment (GATE) has obtained valuable data on the structure of the boundary layer over tropical oceans, from instruments suspended on a balloon cable tethered to HMS *Hecla.* The second major experiment (CABLE) took place in July and August in southern England. The aims here were twofold: firstly to compare different systems used for determining the heat and energy balance within the boundary layer, and secondly to provide data on the evolution in time and space of the daytime convective boundary layer for validation of various theoretical models. This was a joint venture between the Meteorological Office, who used balloon-cable-borne sensors, radiosondes and radar, Reading University, who used a powered glider, Imperial College, who used an instrumented aircraft and radiosondes and the Appleton Laboratory, who provided radar observations. Analysis is currently proceeding of the data collected during several of the better periods.

Other studies, both theoretical and experimental, are being made into the night-time boundary layer and its complex behaviour, and into the physical processes taking place at the top of the convective boundary layer that lead to its overall deepening. The marine boundary layer is the subject of special study including the effects of sea spray on the evaporation process.

Recently consideration has been given to the role played by the various properties of the boundary layer in numerical forecasting on different time-scales in order to highlight those particular aspects which should be well modelled in the forecasting schemes, and also those where present understanding is rather inadequate.

The scientific staff at Cardington maintained and improved the facilities for studying the turbulence structure in the planetary boundary layer by measurements from the cable of a tethered balloon. The study of earlier experiments is continuing including analysis of experiments conducted jointly with the U.S. Air Force Cambridge Research Laboratories in 1973.

The scientific staff at Porton continued to provide the meteorological assistance required by the Chemical Defence Establishment and the Microbiological Research Establishment.

Studies related to air pollution

The work in this field is dominated by the Office participation in the United Kingdom co-ordinated effort on long-range transport of air pollution which is associated with the major Organization for Economic Co-operation and Development (OECD) investigation into European sulphur pollution (with special reference to the low pH values of freshwater lakes in Scandinavia). The results of airborne sulphur sampling flights in 1971 and 1973 off the east coast of the United Kingdom and off the Danish and Norwegian coastlines have been analysed. They indicate a typical velocity of dry deposition of sulphur dioxide on the ground of about 0·8 cm/s, resulting in about a 30 per cent loss to the ground within the United Kingdom in dry conditions of the sulphur dioxide created internally by fossil-fuel combustion, and a virtually complete loss in rain. Various statistical studies and a detailed trajectory analysis, using a fairly complex model simulating all the major sources and sinks of airborne

sulphur, are providing a clearer understanding of the relative importance of the contributions from each distant and local source region to the total deposition of sulphur on Norway and Sweden.

The operational forecasting scheme of daily-average values of sulphur dioxide concentration within London, being run by the London Weather Centre, has worked very well during its first year. The effect of the major fuel crisis in February showed up very clearly when overall emissions appeared to fall by about 40 per cent.

High atmosphere

As a result of activities during the rocketsonde comparison trials at Kourou (5°12′N, 52°44′W) in the autumn of 1973 in which some daylight firings were undertaken to determine temperature profiles in the approximate altitude range of 65 to 20 km, a critical assessment of the available correction techniques was made in order to eliminate the effects of radiation error from the results. This assessment revealed an error in the existing technique which has now been corrected.

Considerable effort has been devoted to an analysis of the performance of SKUA 2 rockets fitted with drag buttons and, as a result, the Ordnance Board gave clearance for the use of these vehicles for a firing campaign in the Hebrides during August. The five rockets used yielded sets of stratospheric temperature data for comparison with temperatures derived from radiometric observations provided by the NIMBUS E satellite, the rocket firings being timed to be in near coincidence in space and time with overpasses of the satellite. These data are being analysed and are expected to provide a measure of 'ground truth' for the satellite observations as well as establishing a technique whereby the performance of radiometers flown in future satellites may be judged.

During these trials the SKUA 2 rockets achieved satisfactory apogees but it was discovered, more or less fortuitously, that the spent rocket motors were taking much longer to fall to earth than had previously been thought. This effect, which was reported to the Ordnance Board, has required a change in the procedures adopted for the firing of the rockets. Since the new procedures are more restrictive than those adopted earlier, trials are in progress to determine the cause of this long fall-time. It is hoped to eliminate this fault by suitable modifications to the rocket motor.

During December a winter firing campaign commenced in the Hebrides as part of an internationally agreed effort to provide stratospheric data for the further investigation of the so-called 'stratospheric warming' phenomenon. One or two rockets per week are being used and the rate of firing will be increased to three per week if and when the stratospheric circulation becomes disturbed.

Efforts have continued to improve the performance of ground and other equipment associated with the SKUA rocket programme. Radar fixes of the descending sonde and parachute which are ejected from the rocket at apogee can now be obtained at $\frac{1}{2}$-second intervals. A new parachute, of the disc–gap–band type, which should provide a slower rate of descent for the rocketsonde at high levels, thus leading to better results, has been successfully tested at low levels but a single rocket ejection trial failed.

A paper has been written which deals with the diurnal variation of wind and temperature in the tropical stratosphere above Kourou. This will be submitted for publication shortly.

No experiments have been flown on SKYLARK and PETREL vehicles in 1974 but, as anticipated in the last *Annual Report*, the results of earlier experiments have been published. These concern the geometric albedo of the moon in the ultra-violet band and the concentration of ozone between 65 and 75 km at night. Another paper concerned with the water-vapour content of the stratosphere has been submitted for publication. Work on the analysis of data from a joint ozone/molecular-oxygen measuring SKYLARK rocket flown from Woomera has proceeded. An ozone profile has been deduced based on results provided by two sensors which provided somewhat different indications of ozone amount. The difference has been attributed to the variations with temperature (and hence with height) in the absorption coefficient of ozone for radiation at the wavelengths concerned. For molecular oxygen the amount observed was considerably less than would be expected from an air-density measurement made close to the same time and place by the falling-sphere technique. The reasons for this difference are thought to be uncertainties in knowledge of the solar spectral intensity and sensor sensitivity in the spectral region used for measurements. Laboratory facilities for measuring sensor spectral sensitivity in the region of interest have been improved.

Work has continued on the design of experimental equipment and procedures to measure the diurnal variations of ozone by the use of PETREL rockets.

Co-operation with the National Physical Laboratory in the development of a broad-band radiometer has continued. This instrument is intended to measure ozone, water vapour and carbon dioxide in the stratosphere and to be of sufficiently small size and weight to be flown on small balloons of the type used as a routine in radiosonde work. Results from an early flight were unsatisfactory in that the instrument took up a large swinging motion during flight and had no reference radiation source included. Addition of the latter increased its weight to beyond that which could be supported on a small balloon so a complete rebuild was undertaken using every means of lightening it. Eventually an acceptable weight was achieved. In order to reduce substantially the excessive angles of swing, a series of flights using a swing sensor was undertaken with a variety of balloon-rig arrangements. As a result a technique using two balloons was established which yields the desired conditions. The lightened radiometer was successfully flown in September from Larkhill, and an analysis of the results shows that the method is sound but that a radiation detector of better performance is required in the radiometer.

Work has continued with the meteor trail radar equipment which, in principle, is capable of measuring winds in the 80–110-km height interval by observations of the movements of ionized trails produced by meteors entering the earth's atmosphere. Earlier use of the equipment showed the need to locate the positions of the trails in space, that is to determine the angles of arrival of 'returns'. Various modifications to the aerial and receiver systems to enable this to be done were tried out, without much success. A system in use at Sheffield University may solve the problem but its performance had never been fully assessed, so a joint exercise involving the use of a helicopter of the Army Air Corps Demonstration and Trials Squadron was arranged to measure the sensitivity pattern of the Sheffield system; the data are now being analysed.

The high-powered dye laser for the determination of atmospheric density and aerosol content has been kept in operational condition throughout 1974 although the power restrictions experienced early in the year and the generally poor weather of the summer severely limited the number of occasions on which the equipment could be used. The laser output is now 50 per cent greater than its original design figure, firing stability has been improved as has the operation of the fast rotating shutter, and operation at a second, shorter wavelength has been achieved. These improvements have resulted in higher accuracy in the Raman scattering profiles for the stratosphere, this equipment being the second in the world to obtain such data. Comparisons between Rayleigh and Raman profiles are being made and experiments to obtain Rayleigh–Mie scattering profiles at two wavelengths are planned to improve the interpretation of the results in terms of aerosol layers. A paper has been published which deals with the signal-induced noise effects in photomultipliers. These effects were discovered as a result of the study of noise sources in the experiment. A second paper shows that the effects of photomultiplier noise may have led to significant errors in laser-radar results published hitherto.

The measurement of total atmospheric ozone by ground-based Dobson spectrophotometers has been undertaken at Bracknell, Lerwick and Gan, and the results have been sent to the international ozone data centre as a contribution to the world-wide monitoring network. Our standard instrument was taken to Poland in the summer for comparison, under WMO/Commission for Instruments and Methods of Observation (CIMO) sponsorship, with similar instruments from a number of other countries.

Satellite projects

Support for two satellite projects has continued during 1974. The European Space Research Organization (ESRO) meteorological application satellite, METEOSAT, has required attendance at a considerable number of European committee and working group meetings. One staff member has acted as a consultant to ESRO in the general field of data interpretation and some 'in-house' studies have been undertaken. The Office has filled the chairmanship of the scientific and technical group which reports to the Programme Board on which the Director-General sits as one of the two United Kingdom members.

A 'Memorandum of Understanding' was agreed between the U.S. National Oceanographic and Atmospheric Administration (NOAA) and the National Aeronautic and Space Administration (NASA) on the one hand, and the Office on the other hand, which sets out the responsibilities of the various parties in the provision of stratospheric sounding units (SSUs) and their integration in the next generation of orbiting meteorological satellites, known as the TIROS N series. The first satellite in this series is expected to be placed in orbit in 1977. The supply of SSUs is a Meteorological Office responsibility and is the subject of a contract with Marconi Space and Defence Systems Limited. Design and construction work has gone ahead but this was inhibited to some extent by a change in U.S. satellite plans, which, in turn, required changes to the specification of the SSU. A reworking of certain aspects of the design became necessary together with a rescheduling of the project plan. Visits have been made to the U.S.A. in order to co-ordinate the work. Delivery of a radiometric calibration plant for installation and use at Bracknell as part

of the overall programme has begun, though its completion will be somewhat delayed owing to the non-availability on schedule of certain materials required for its construction.

Several theoretical studies have been made in support of this programme. These include a study of the most appropriate scan patterns for the SSU and another on the filter characteristics required in the instrument.

Interpretation of satellite-borne instrument measurements

An orbiting satellite has the merit that it can view substantially the whole of the earth's surface twice a day and, if observations of atmospheric conditions important to the practice of meteorology can be deduced from the output of instruments so deployed, such observations can be obtained from even the most remote areas where conventional means would be unacceptable because of cost. The conversion of measurements of radiant energy leaving the earth's atmosphere—which are all that a satellite can provide—into meteorologically useful quantities is, however, not a straightforward process. Several studies have been undertaken to enable more effective use to be made of radiance data from satellite instruments.

Samples of Vertical Temperature Profile Radiometer (VTPR) data from the instrument carried on the NOAA 2 satellite have been obtained from the U.S.A. and used to deduce thicknesses from 300 to 30 mb over north-west Europe. A start has been made on the development of computer programs for deducing tropospheric temperatures and humidity profiles, cloud height and cover from the same data. Meanwhile the feasibility of obtaining direct read-out of these VTPR radiances from the spacecraft over a limited area has been demonstrated by the Space Department of the Royal Aircraft Establishment at the request of the Office. Successful retrievals of sea surface temperatures, cloud height and cloud cover have been achieved by the use of very high resolution infra-red radiances derived from the NOAA 2 satellite, and work on similar lines using Scanning Radiometer (SR) digital data will be done when data are available. Work is in progress, using NIMBUS 5 radiances, on the production of computer-drawn charts of mean daily stratospheric radiances and thicknesses in preparation for the receipt of information from the projected TIROS N SSU. In this connection different methods of retrieving the thicknesses have been studied. Finally a comparison has been made of near-coincident radiosonde ascents and data deduced by NOAA from VTPR soundings, and further comparisons are being undertaken.

Stratospheric analysis

On 1 April daily analyses of the stratospheric conditions at the 50-, 20- and 10-mb levels commenced for the northern hemisphere north of about 20° latitude. The observations are plotted automatically and the 10-mb chart is finalized some 6 days after the event, when all rocket observations have been received and processed. These charts are used to calculate various parameters including zonal and meridional flow, kinetic energies in the first three wave numbers and the vertical flow of energy through the 100-mb level. Objective analyses by computer at the 50-, 20- and 10-mb levels are compared with hand-drawn charts and quantitative estimates (and the locations) of major errors in the objective analyses are made. These should help in developing

methods to improve the computer analysis. Stratospheric data during the 'warming' of February 1974 are being analysed by means of isentropic charts to describe the three-dimensional flow and its evolution with time. Vertical velocities of about 8 cm/s at 20 mb have been found.

Meteorological Research Flight

The programme of the Meteorological Research Flight (MRF) during 1974 was dominated by the use of the newly delivered C-130, Hercules, aircraft in the GARP Atlantic Tropical Experiment (GATE). At the end of 1973 the aircraft was delivered to MRF, after extensive modifications to adapt it to its research role which were described in last year's *Annual Report.* The early part of 1974 was occupied with the wiring, installation and testing of the basic meteorological instrumentation and recording equipment. The sensors include wind vanes and pitot-static systems which, together with the 'stable platform' and Doppler navigation system of the aircraft enable vertical and horizontal wind components to be measured with errors of less than about 0·2 and 2 m/s respectively; several types of thermometers and hygrometers, including ones with sufficiently rapid response to allow the estimation of eddy fluxes of heat and water vapour; an infra-red radiometer (8–12 μm); a 3-cm weather radar; a downward-facing Vinten camera; forward-facing TV cameras with monitor screens in the control position within the aircraft, and facilities for air sampling and for the ejection of dropsondes. The control and recording gear for the instruments is mounted in a removable recorder van which provides a reasonably quiet working area. This instrumentation together with the long endurance and good communications equipment of the aircraft make the MRF Hercules one of the most versatile meteorological research aircraft in the world.

The installation was completed in time for a few days' test flying before departure for the GATE Headquarters at Dakar on 24 June, five days before the start of the first phase of intensive observations.

The area of operation for the aircraft in GATE was located about 1000 km to the south-west of Dakar where the research aircraft—between 10 and 14—from four nations were based. The Hercules was one of only 3 aircraft equipped to make measurements of the vertical and horizontal fluxes of momentum, heat and water vapour, so it was used exclusively for flights in the lowest 2 km, with other aircraft making observations at higher levels up to 10 km.

During the 10-day intervals between the intensive observational phases, the aircraft and crews (MRF observers, RAF aircrew and RAE groundcrew) returned to Farnborough for a 'Base 1' inspection and servicing. Some parts of the experimental equipment had deteriorated in the hot, humid conditions encountered, and they were removed, refurbished, calibrated and re-installed before departure for the next phase. At the same time, the opportunity was taken to change some of the MRF observers, so that as many as possible could become familiar with the new aircraft and could experience participation in a major international scientific project.

The aircraft finally returned to Farnborough after completion of the project on 23 September. During the three intensive phases it had flown on 40 scientific missions for a grand total of 336 flying hours. The serviceability of the aircraft and its equipment was excellent; it flew on and completed every mission allocated to it and was late on take-off on one occasion only. On 10 missions the Hercules was used as the lead aircraft by the airborne mission

scientist in charge of the day's operations. It is estimated that during the GATE period about 10^9 items of meteorological data were collected, the processing of which will take $1\frac{1}{2}$–2 years.

The Canberra aircraft was grounded for most of the year for a minor inspection and for installation of infra-red and submillimetre radiometers. First flights with these instruments were made towards the end of the year.

The Varsity aircraft was used in continuation of the work on transport of sulphur dioxide and on cloud electrification described in last year's *Annual Report*. These projects have progressed rather slowly because of their dependence on suitable weather, and the planned withdrawal from service of the Varsity in 1974 has been postponed until 1975.

Geophysical fluid dynamics

Investigations of fundamental dynamical processes in rotating fluids bear directly on the development and practical application of theoretical ideas in meteorology and oceanography and on the study of planetary atmospheres. The Geophysical Fluid Dynamics Laboratory of the Meteorological Office carries out a range of such studies, with the main emphasis on laboratory experiments made under reproducible and controllable conditions, but with a growing interest in numerical experiments using high-speed electronic computers. Combined laboratory and numerical studies can be particularly valuable, especially in the assessment of the reliability and range of validity of complex numerical schemes and in elucidating details which are not readily investigated by laboratory methods alone.

During the course of 1974 an extensive series of laboratory experiments on baroclinic waves was completed. These play a key role in the large-scale circulation of the earth's atmosphere and may, according to recent evidence, also be important in the oceans. A particularly interesting result found in an analysis of the behaviour of different harmonic components is the occurrence of sudden but regular changes in amplitude and phase. (Comparable analyses were subsequently carried out on the results from certain numerical models. Certain long-wave components in the 10-level model have thus been found to undergo unexpected and sudden changes in phase and amplitude.) Spectral analysis of irregular flows elucidates aspects of geostrophic turbulence by indicating the conditions under which various theoretical hypotheses should apply. The next series of experiments on baroclinic waves will be directed towards various questions posed by considerations of the structure of the ocean thermocline and of statistical aspects of climatic change.

The Atlantic Tropical Experiment of the Global Atmospheric Research Programme (GATE)

From June to September 1974 the United Kingdom made a substantial contribution to a major international experiment to study the weather of the tropical oceans. This experiment had been mounted in the tropical Atlantic as part of the joint WMO/ICSU Global Atmospheric Research Programme (GARP). Its aim was to discover how the development of tropical weather systems is linked with the larger-scale atmospheric circulations and to find out how the tropical weather disturbances both control and are controlled by the world-wide atmospheric circulation. Altogether 40 ships and 13 aircraft from 13 countries took part.

The Meteorological Office co-operated with the Navy Department, the Institute of Oceanographic Sciences, Imperial College and the University of Southampton in providing the United Kingdom contribution to the experiment (see Plates II and III). Four British ships participated in the experiment—HMS *Hecla*, RRS *Discovery* and two ships specially chartered by the Meteorological Office, the *Charterer* and *Endurer*. A Meteorological Office team on board *Hecla* made special soundings of the lower atmosphere from the cable of a tethered balloon, and surface observations from a buoy, with a view to examining the turbulent-transfer processes over the tropical ocean. The Meteorological Research Flight C-130 aircraft also took a very active part in the observational programme. It operated from Dakar where the central control facilities for the experiment were established. The Meteorological Research Flight personnel took an active part in the day-to-day planning and operation of the experiment.

The *Charterer* and the *Endurer* occupied positions to the north-west and east of the main experimental area in which cloud systems were studied in detail. The role of these two ships was to observe the main air currents in which the cloud systems were embedded. For this purpose they maintained regular upper-air soundings and surface weather observations including radiation measurements. Upper-wind measurements were made by means of the new LOCATE system. Satisfactory results were achieved after initial technical difficulties.

Contributions of the Meteorological Office to the GATE programme are also mentioned elsewhere in this report in association with the scientific programmes of the participating groups.

Dynamical and Synoptic Research

Research related to short-range weather forecasting

The weather forecasts which are issued for one to three days ahead are largely based on computer calculations of the expected atmospheric circulation and pressure field. These calculations are carried out on the basis of the physical and dynamical laws applied at 10 levels in the atmosphere (the so-called 10-level model). Considerable effort is being directed to refine and improve the technique.

An improved mathematical technique was developed for the hemispheric predictions by using a semi-implicit integration method. This was introduced on 29 October and has resulted in a significant saving of computer time. A further reprogramming of the calculations has been started to operate on a grid of 150-km mesh in place of the current 300 km.

Calculations are carried out on a finer grid of points (100-km spacing) over the Atlantic and Europe than over the rest of the hemisphere. A new technique has been developed by which the boundary conditions on the fine grid are determined. This specifies the inflow across the boundary from the hemispheric calculations and the tangential velocity at inflow points primarily; at outflow points the tangential velocity is determined by extrapolation from the interior.

Experiments to model the boundary layer near the ground at the topographic height rather than at 1000 mb, the lowest model level, have been

successfully completed. In addition to producing more realistic developments in regions of high topography in both the hemispheric and fine-mesh models, the scheme allows the use of a reduced lateral diffusion coefficient. This has beneficial effects, particularly on jet-stream maximum wind speeds.

A new treatment of the deep convective clouds and showers based on a modified form of Kuo's (1965) scheme nears completion. Some care is needed in formulating the scheme in temperate rather than tropical latitudes. Realistic rainfall patterns are being produced, and the results are being assessed.

Hitherto the radiative heat loss of the atmosphere has been neglected in short-period forecasts. A scheme to incorporate this has now been developed; this computes long-wave loss to space, long-wave interactions between model layers and includes the effects of clouds and the ground as black or grey bodies. Three six-day integrations have been made with the hemispheric model, and the results are very encouraging. This scheme has also been used with the fine-mesh model, with significant beneficial effects on the rainfall forecasts.

Progress has continued on a mathematical model which will compute in more detail the development of meteorological systems in the lowest 2 km of the atmosphere. Problems arise from the necessary relaxation of the assumption that the atmosphere is in hydrostatic equilibrium, but these have been largely overcome. The first test of the model will be in regard to the development of the sea-breeze circulation on a summer day in southern England. It is, however, hoped that the model will ultimately provide an important aid to understanding and forecasting other local weather developments.

Work has continued on a project to estimate automatically surface weather parameters such as surface wind, temperature and cloud cover, in addition to rainfall from the forecasts produced by the fine-mesh version of the routine forecasting model and to display these in the form of a local-area worded forecast. Rainfall distributions have been derived on a 20-km grid from the model predictions on a 100-km grid, allowing for local exposure. The incorporation of surface observations into the local forecasts is being investigated. While reasonable results have been obtained with temperature and cloud forecasts, progress with an objective forecast of fog has been slow, partly because the lack of foggy situations during the year has prevented testing of the routines. Convective rainfall and thunder forecasts await the introduction of improvements in the 10-level model prediction of deep convection.

An analysis of long-wave patterns in octagon 500–300-mb thickness forecasts has shown that the model often does not handle the long waves correctly. In view of the relevance of these results to extended-period forecasts, further work is being carried out to determine the source of these errors which is thought to be connected with the handling of the non-linear interactions between the waves with the present finite different grid size.

Statistics of the performance of both octagon and rectangle versions of the 10-level model have been collected in an attempt to identify consistent areas of bias in the model. Such features include a continuous drying out and cooling of the lowest layer of the model over the sea in winter, possibly connected with inaccuracies in the treatment of the surface exchange processes. It is hoped that these statistics will also provide a yardstick against which the effects of future modifications of the model can be tested.

Observations from weather ships, particularly measurements of upper-air temperature, pressure, wind and humidity have always been considered

essential material for routine objective analyses and the progressive withdrawal of U.S. weather ships from the Atlantic during 1973 and 1974 was expected to have a detrimental effect. During the same period, measurements of upper-air temperature derived from satellite data have become available as a routine and these, though known to be less accurate than radiosonde reports, might be expected to compensate partly for the loss of the ships. Early in the year two short experiments were carried out, each involving a duplicate set of computed analyses and forecasts, run in parallel with the operational version. In the first experiment, an assessment was attempted of the effect of omitting weather-ship reports altogether, and in the second, satellite data were incorporated in the analysis procedure.

The omission of all weather-ship reports resulted in some deterioration in the ensuing forecasts though over this limited period the differences were not large. There was some evidence that the removal of the U.S. Atlantic weather ships has already led to some loss of accuracy, in that observations from remaining weather ships were harder to assimilate in computed analyses. In the second experiment, the inclusion of satellite data resulted in slight improvements overall in forecast accuracy, but it was clear that these reports would be much more useful if they were more reliable. Following these experiments, satellite reports of upper-air temperature began to be used as a routine in the operational suite, though careful human monitoring of their quality is necessary.

Attention is being given to methods of improving humidity analyses, and hence the rainfall forecasts. The feasibility of using subjectively interpreted satellite cloud photography to infer humidity values is being investigated. Also efforts are being made to use reports of cloud and weather from surface observations to estimate humidities at upper levels.

General circulation of the atmosphere

To understand the general circulation of the atmosphere fundamentally is one of the major aims of meteorology. The ability to simulate it numerically depends on this understanding and is a practical goal whose importance is growing as it is realized that anomalies of weather and climate are important factors in the world's food supply. It would be desirable to anticipate any vagaries of weather and climate, be they natural or, as is increasingly possible, man made. Numerical models of the climate offer the hope that ultimately advance warning might be given of some of the weather variations which could have widespread disastrous consequences. At present, models are capable of producing surprisingly realistic simulations of the normal circulation of the atmosphere on a large scale but there is many years' work ahead before they can be considered good enough to predict reliably what would happen if the normal conditions were disturbed.

The study of the general circulation of the atmosphere has involved the creation of global numerical models whose simulations of climate are being continuously and systematically improved by incorporating better physical descriptions of processes in the atmosphere. Most of the work has used a 5-layer model with a horizontal grid separation of about 330 km. Simulations of the global climate for January and July were produced by a version of this model

which incorporated a simple variable-depth boundary layer at the earth's surface. In a number of important respects the simulations were better than those obtained previously with a simpler boundary treatment; notably as regards the rainfall and wind-flow patterns in the tropics and in the realism of the cyclonic belt of the southern hemisphere. Experiments are continuing to improve the model further.

Study of the changes in climate simulations produced by sea surface temperature anomalies continued to be a major interest. When the anomalies are in the tropics or subtropics, numerical models predict a significant response in higher latitudes which can be verified against observations. Further investigation, involving a series of numerical experiments isolating this effect, demonstrated the mechanism by which middle latitudes are affected. Exploitation of the results provides a possible means of improving long-range weather forecasts, though it has to be recognized that any success would be in a statistical sense; all individual occasions cannot be expected to follow the predicted bias. A series of experiments to find out whether the numerical models are useful for this purpose has been started. The differences between climate simulations with normal and actual sea surface temperatures will be compared with subsequently observed weather anomalies, and the results subjected to statistical investigation to determine whether it would be advantageous to add this method to others already used in long-range forecasting.

Considerable effort has been devoted in recent years to devising methods for computing radiational heating and cooling rates in general circulation models. The effect of clouds, which is crucial, presents many difficulties, not least because the essential physics is not completely understood and there is disagreement about the values of fundamental parameters. A scheme has been produced which allows representation of one or two layers of cloud, the amounts being variable and dependent on the humidity in the general circulation model. Climate integrations have been carried out with the scheme and have been shown to produce acceptable simulations. Experiments are continuing to find out how sensitive they are to variation of the radiation parameters. The scheme is also being used in a climate perturbation experiment in which the amount of cirrus assumed for a particular humidity is increased by 25 per cent. It is hoped that this and other similar experiments involving other atmospheric variables will help to provide some indication about how sensitive the present climate is to atmospheric changes of a kind which might be caused by man's activities.

The aim of the international First GARP Global Experiment (FGGE) now scheduled to begin operationally in the latter part of 1978 is to provide a comprehensive, day-by-day description of the global atmosphere. To achieve this it is planned to supplement the regular observing network by special observations of various kinds in places where data are sparse. In tropical regions, atmospheric soundings will be obtained from instruments dropped on command from floating balloons; in the southern hemisphere, the vast oceanic areas will be 'observed' by constant-level floating balloons, and by unmanned floating ocean buoys. Experiments have been carried out to provide the planners with evidence concerning the effectiveness of possible observing systems. Simulated 'observations' were derived from a run of the 5-layer general circulation model and were adjusted to incorporate the errors expected from the various measuring devices. They were then used as data for a less-sophisticated forecasting

model, and the closeness of the analyses to the original flow patterns was monitored to see how closely the complete global circulation of the atmosphere could be reconstructed from the data arising from the proposed observing system. The evidence from the experiments cannot be taken as conclusive since it depends to some extent on the characteristics of the models. It did, however, draw attention to additional factors which should be taken into account in specifying the observational requirements. The results have been made available to the international Joint Organizing Committee for GARP.

In comparison with the 5-layer, the 11-layer general circulation model has a considerably enhanced capability of representing both the horizontal and vertical structure of the atmosphere. It therefore requires much more computing time, and this limits the period for which simulations can be produced. Development of the model is at present being carried out mainly by testing its forecasting performance for 6–10 days ahead. Both hemispheric and global forecasts have been produced. The results are encouraging, even with the first working version. However, areas where the physical parameterization can be improved are readily pin-pointed. Recently attention has been concentrated on the representation of processes in the boundary layer, the lowest region of the atmosphere in which the earth's surface has a substantial influence upon the flow. An attempt has been made to delineate the physical processes there more accurately than in previous general circulation models. Forecasts already made for a week ahead demonstrate that whereas the effect of minor changes in the boundary-layer formulation is small when judged on a global scale, it can be substantial on individual atmospheric features, and is therefore clearly important in medium-range forecasting.

The boundary-layer description was initially based upon investigations carried out in Australia, but a general circulation model has to be able to deal reasonably with conditions in all parts of the globe. Extremes, such as are encountered over Siberia in winter or over tropical deserts at midday, have to be encompassed. The original treatment, extended beyond the limits justified by actual measurement, gave results which seem physically unrealistic. The formulation has been changed to be more acceptable and special studies, both numerical and theoretical, are being carried out to try to further understanding of fundamental boundary-layer properties.

During the year, the exploration of the 'finite-element' method for integrating the equations of numerical models was carried further. The method has been shown to have computational advantages in idealized situations, and might eventually therefore replace the 'finite-difference' approach generally used. Tests are now being carried out in which it is applied to a full version of the 5-layer general circulation model to discover whether the benefits evident in simple cases can also be realized in more-general circumstances.

Descriptive studies of the general circulation of the atmosphere are also maintained. These are of interest in themselves but will also provide a basis for testing numerical models. Comparative circulation studies using indexes of surface westerly wind have been carried out for three oceanic regions—the west and east Pacific (divided at 175°W) and the Atlantic. The latitude belt 35°–55°N has been chosen as the best for the three regions for the various seasons of the year. Most attention has been devoted to the circulation in the winter half-year. The indexes reveal that the maximum of the winter circulation is reached on average a month earlier in the Pacific than in the Atlantic. The

mean December–January peak in the Atlantic is interesting for several reasons; among them may be mentioned:

(a) The increase in strength between November and December and the decline between January and February is disproportionately greater than the increase and decrease of the temperature gradients both over the Atlantic and over eastern North America at these times.

(b) During some epochs the peak has been clearly in January, e.g. 1920–40 and in others, e.g. 1950–60, clearly in December.

(c) A separation of the winters into odd and even, depending on the year in which January falls, reveals that over the whole period 1900–69 the mean peak was reached in December in the odd years and in January in the even years.

During the year work was done on examining the role of the quasi-biennial oscillation in the general circulation. The preliminary results are necessarily tentative owing to the short period for which stratospheric data are available. Nevertheless there is some evidence for suggesting that, at least in January and July, the phase of the quasi-biennial oscillation in equatorial stratospheric winds does influence the circulation patterns in the troposphere over the hemisphere generally and particularly in the Atlantic sector. The tropospheric jet stream appears to be somewhat further south in summers and winters when the quasi-biennial oscillation is easterly compared with occasions of the westerly phase.

Charts of mean wind, temperature and contour height at the 30-mb level over the northern hemisphere for October and for areas north of 45°N for August and September have been prepared for publication. This set of charts and diagrams completes the project describing the climatology of the 30-mb level, including the quasi-biennial oscillation in equatorial stratospheric winds and the spring and autumn reversals of stratospheric winds over Scotland.

Tropical meteorology

During the summer, the GARP Atlantic Tropical Experiment (GATE) took place. It provided an opportunity to test numerical models in the tropics which are still not well understood meteorologically, but are of great importance in general circulation studies since they are areas where energy is put into the atmosphere and from which it later spreads to middle latitudes. A version of the 11-layer model covering parts of the Atlantic, Africa and South America was prepared in advance of the experiment, and during it was used for forecasting up to 24 hours ahead. The forecasts were 'updated' by new observations, a further forecast was made and the process repeated. This method, termed a 'forecast–analysis cycle', is similar to the procedure at operational forecast centres and is essential for the production of acceptable analyses over a wide region and over an extended period. A substantial effort was devoted to developing new methods of analyses appropriate to the equatorial region—these are necessarily different from those used in higher latitudes. Throughout the three main phases of GATE, the forecasts were monitored and the performance of the forecasting model assessed.

The main difficulty facing conventional numerical models in the tropics is that the greatest activity takes place at scales smaller than the grid-point separation. Large-scale features which are well described in the model are weak

while the heat and moisture transports are affected largely by individual clouds or cloud clusters. They cannot be described explicitly and have to be allowed for ('parameterized') in terms of the large-scale flow. One of the prime functions of GATE was to provide sufficient data on the statistical effect of many areas of deep cloud on the atmosphere for efficient parameterizations to be devised. It was expected that the main errors in the tropical forecasts would be related to the treatment of convection, and this indeed proved to be the case. The problems involved in getting this right are fundamental and no ready solution is at hand. However, GATE has provided a unique data set for the purpose, and every effort will be made to use it profitably.

A vast quantity of data was obtained as a result of international effort during GATE. It must be collected, scrutinized and validated before being made available to scientists through the World Data Centres in New York and Moscow. The Meteorological Office has undertaken the prime responsibility for this work in respect of the synoptic-scale data. Already well over 100 000 observations have been collected; others will continue to arrive during the next year or so from the countries responsible for making them. The 'quick look' data set, which will contain most but not all of the data, and on which only a limited amount of checking will have been carried out, is expected to be ready on magnetic tape for distribution early in 1975.

Work has already begun on the final data set which should be complete and free from errors. To achieve this will require the close study and intercomparison of observations made by many nations using a variety of different measuring devices. It represents an exercise in data handling of a kind which has probably never before been attempted.

Research related to long-range forecasting

The issue of weather forecasts for 30 days ahead has continued as routine throughout the year. They are prepared independently for each calendar month and for each mid-month to mid-month period and are made available to the public through television, radio and the Press. A more detailed document giving weather statistics for representative places in Britain together with the detailed forecast is also available to subscribers at a very small cost. The number of subscribers to this service has remained fairly steady at around 1700. It is not possible to predict day-to-day weather on this time scale but an experimental 7-day forecast prepared in conjunction with each 30-day forecast usually gives good guidance for the first week, and techniques have been developed which enable the broad weather types in different parts of the month to be distinguished, if these are likely to be notably different from one another. For these forecasts the United Kingdom is divided into 10 districts, and for each district the forecast gives the expected mean monthly temperature anomaly as one of 5 categories (each equally likely over a long period of years) and rainfall in one of 3 similar categories. Attempts are made in winter to predict whether frost, fog, gales and snow will occur more or less frequently than usual and in summer the expected amount of sunshine and thunderstorms are related to the averages. The year 1974 was an unusual one, a very mild winter being followed by an exceptionally dry spring, a notably cool summer and a very wet and cold early autumn. Despite these variations the success rate of the forecasts was maintained.

Research into long-range forecasting continues to be mainly statistical in character. One area of progress has been in the development of the methods started last year whereby a discriminant technique is used to find the significantly different precursors (say of 500-mb height or surface pressure on a hemispheric chart) preceding divergent weather samples. The technique has been used, for example, by selecting those 20–25 years in the past in which, say, the Septembers had been similar to the current year as regards mean temperature and rainfall. It is usually found that the following 20–25 Octobers include warm and cold years and also wet and dry years but the discriminant technique enables an objective decision to be made as to whether the current year resembles the precursors to the warm or cold sample (or wet or dry).

It is recognized that heat sources and sinks occupy a major role in the determination of anomalies in the annual progress of the general circulation. These sources and sinks had been considered only qualitatively in the long-range forecasting procedure but a program has recently been developed to measure quantitatively the non-adiabatic heating and cooling of the 1000–500-mb layer of the troposphere by radiation and by transfer of sensible and latent heat from the boundary layer. It is intended to calculate the daily non-adiabatic heating and to form pentad means over much of the northern hemisphere and study their relationship to subsequent atmospheric developments.

A powerful method of analysing the variations of circulation types in individual years for a particular season is the eigenvector technique. This technique expresses the complex variation from year to year by a discrete number of virtually independent patterns which represent characteristic anomalies within the normal circulation for that particular season. The value of the technique lies in the fact that the first five eigenvectors of each season account for about 80 per cent of the variance in the evolution during the particular season. It is of great interest that statistically significant correlations have been discovered between the eigenvectors in a season and the eigenvectors of a season as much as ten months ahead. This implies that the circulation evolution operates on a relatively long time scale, i.e. the pattern of January and February may depend more upon the pattern of the previous March–April than the pattern of November–December.

Objective indices of surface pressure, wind flow and vorticity for each of four areas, the British Isles, the central North Atlantic, the Baltic, and the Aleutians have been catalogued from 1881 to date. These have been used in matching the evolution of monthly and seasonal weather types over the hemisphere with those for other years, and in the selection of analogous weather types for forecasting and research purposes.

Although it is not yet possible to give a seasonal forecast, many of the statistical methods applied to monthly forecasting can be adapted to the longer time scale. Experimental seasonal forecasts are being made regularly by these methods and show approximately similar success to the monthly forecasts. The demand for seasonal weather forecasts from industry, agriculture and government sources indicates a growing realization of the potential value of such information. The demand is being met as far as possible by the issue of statistics which give an idea of the probability of a warm/cold or wet/dry season to follow.

Some work has been done on trying to find precursors in the general circulation to dry and wet years in the West African marginal rainfall areas

(Sahel). It was shown that the mean pressure anomaly in April and May in the six wettest years was almost equal and opposite to that in the same period in the six driest years in the area between Scotland and Norway, so that a knowledge of the pressure anomaly in that region in April and May appears to give an indication of the expected rainfall in the Sahel in the summer.

In order to establish statistical rules a large amount of past meteorological data is necessary. During the year a new data set of marine observations has been started which in the course of the next year is expected to include some 40 million individual observations covering much of the world's oceans and extending back in time into the nineteenth century. This data set will be used further to study the relationships between sea temperature anomalies in various areas and the general atmospheric circulation.

Because of the unique nature of our data bank, parts of it are in almost constant demand from other national meteorological services and universities all over the world. In 1974 sales or exchanges completed or in hand included the U.S.A., U.S.S.R., Spain, Poland, Greece, Swtizerland, Sweden, Hungary and Canada.

Considerable progress has been made in implementing the METOCODE system of computer programs in a form suitable for any type of computer. The PILOT 4 implementation, which is intended to provide all the data-handling and statistical facilities needed for long-range forecasting work in a form suitable for general and continual use, is at an advanced stage of testing and should eventually prove suitable for international exchange within the World Meteorological Organization.

Climatic change

A review of the climatic forecasts which have been published by various investigators in the last decade or two has been made during the year. Most of them are based on cycles of 80–90 years or of about twice this length. These are cycles which are displayed, but by no means very strongly or regularly, by the sunspot number. Since the meteorological data do not show these cycles very strongly either, the reliability of the forecasts depends on the closeness of the relation between sunspot number and terrestrial climatic parameters. There is no unanimity among meteorologists on this question, but what is clear (and partly explains the lack of unanimity) is that the amount of the variance in the various climatic parameters which is to be ascribed to sunspot changes is small. It is still a contentious matter whether the solar constant varies by even as much as 1 per cent during the 11-year solar cycle or not, and there is scarcely the data to make any statement about its behaviour during the so-called secular cycle of about eight 11-year cycles. It appears likely that the sunspot numbers in the next two or three 11-year cycles will be lower than in those since 1933, but in view of the points made above, this does not give any useful guide to the course of the climate in the next few decades.

The increase in the winter circulation (especially over the Atlantic) from the end of the nineteenth century to a peak about 1930 and the decrease from 1950 to 1970 are regarded as essential elements in the climatic trends of this century and present work is directed to understanding these changes. The relation of circulation strength to temperature gradients is being studied on time scales from 5 days to 5 years. Although on most hypotheses temperature gradient is assumed to be the driving effect, the strongest temperature gradients

over eastern North America in winter occurred nearly 10 years after the circulation peak over the Atlantic. Examination of the relationship for individual winter months has indicated that the temperature gradient over eastern North America explains at most a quarter of the variance of the Atlantic circulation. The explanation of the variations of the Iceland low–Azores high complex, especially in winter months, appears to be a key matter in climatic change.

In view of the renewed interest in possible relationships between the sunspot cycle and weather, as manifested in papers appearing in scientific journals, studies have been made of the variations of a number of climatic indices in relation to sunspot number or phase of the sunspot cycle. No clearly defined relationships have been found. Rainfall over England and Wales tends to be high about 3 years after a sunspot minimum and low 2 years before the minimum. Spring and summer temperature, on the other hand, appear to show some variation over a double sunspot cycle rather than over single cycles of about 11 years.

Special investigations

Special investigations are necessary to meet many requests for meteorological advice which cannot be handled by the main streams of research but which may involve considerable scientific judgement and the appraisal of indirect or scanty information. Some problems, for example the probability of occurrence of very low cloud or poor visibility or of dangerous cross-winds at airports, can be answered by readily available computer analysis of past records but other problems may involve fundamental issues and require more detailed study.

The development of Concorde and its approach to certification have posed several questions relating to the chances of the occurrence of several specific meteorological conditions. Many hours of Concorde flight data have been scrutinized for observations of sudden large changes of temperature, and attempts are being made to assess the likelihood of extreme changes by using other related observations, for example radiosonde measurements of large vertical changes of temperature in the lower stratosphere. To help the assessment of the chances of high storm-cloud tops, radiosonde data are being processed to produce a climatology of potential large-scale convection. Further processing has been made of photographs of radar screens at Gan and Singapore, and computer analysis is being used to provide estimates of the possibility of aircraft encounters with high cloud tops in the tropics.

Clear-air turbulence (CAT) remains a major technical problem for aviation, and work continues on attempts to improve the location and forecasting of CAT. Evaluation of several forecasting techniques has been based on comparison with aircrew reports. Although it appears that a theoretically based method can delineate areas of increased risk, there is as yet little indication that a reliable method of forecasting will be attained.

Several incidents of aircraft having difficulty in their approach to airports have stressed the need for further work relating to the occurrence of large wind shears in the lowest 100 metres of the atmosphere. The frequency of such dangerous wind shears has been assessed on the basis of a series of detailed wind soundings available from Shoeburyness. Another matter of concern to aircraft operators, that of the optimal averaging of wind observations, has also received further attention. Averages over periods of about 5 minutes appear

to give the most representative values for aircraft landing. Other activities have included the supply of climatological reports and route appreciations for aircraft operators, air pollution problems, especially the development of a means of forecasting the lengths of visual plumes from cooling towers, the improvement of methods of estimating storm tide surges, sea spray icing of ships in northern waters and icing in relation to helicopter design standards.

A small team co-ordinates research carried out at outstations in relation to forecasting local weather variations and effects of terrain. Advice and assistance have been given to several investigators covering topics such as sea-breeze effects, standing waves near hills, tornadoes, squall gusts, thermals for gliding, air-mass changes during sea crossings, visibility near motorways, night cooling effects over grass and concrete, and predictors for use in snow and/or hail situations.

The revision of the *Handbook of weather forecasting* was practically completed.

The stratosphere and the effects of aircraft engine emissions

Studies of the possible effects on the human environment of injections of pollutants from the engine exhausts of large fleets of aircraft flying in the stratosphere have continued under the direction of the Committee on Meteorological Effects of Stratospheric Aircraft (COMESA). The research programme includes measurements of stratospheric minor constituents (ozone, water vapour, nitric acid, nitrous oxide and nitrogen dioxide) by groups in the National Physical Laboratory, the University of Oxford and the Meteorological Office. Laboratory studies of the basic photochemistry are being carried out in the Universities of Oxford and Cambridge and atmospheric modelling studies for this work are being made in the Meteorological Office. Measurements of stratospheric composition were made in 1973 by the National Physical Laboratory scientists using equipment installed on the Concorde aircraft and some of their results are now published. This year, in order to gain more information on the vertical distribution of the constituents, measurements were made in France using the large balloon facility of Centre National d'Études Spatiales by both the National Physical Laboratory and University of Oxford groups. New data were obtained and preliminary results were presented at a joint conference with the Groupe d'Études sur les Conséquences des Vols Stratosphériques (COVOS) held at Oxford in September 1974. Further balloon flights in France are planned for 1975, including an attempt by the Meteorological Office to measure directly the heating caused by gaseous and aerosol absorption of solar radiation in the stratosphere. Experiments are being made with the 13-level three-dimensional global model to study the dispersion of trace substances in the stratosphere and also to examine the effects on surface temperature and rainfall that might follow if the radiative conditions in the stratosphere were perturbed as a result of composition changes. Preliminary results indicate that the changes near the earth's surface are likely to be small even when large changes of composition are introduced in the stratosphere. A one-dimensional model including detailed photochemical processes has also been developed to study changes in the stratospheric ozone concentration and the increased penetration of solar ultra-violet radiation that might be caused by large-scale aircraft exhaust emissions. Close co-operation is maintained with other organizations carrying out similar studies overseas, particularly in France and the U.S.A.

General Activities of the Research Directorate

The Meteorological Office continued to work closely with a number of national and international bodies which are concerned with meteorological research. The Office provides representatives on a number of research-oriented committees of the Royal Society, the Natural Environment Research Council and the Science Research Council. In the international field, scientists from the Office serve on several working groups of the World Meteorological Organization and of the International Association of Meteorology and Atmospheric Physics.

Dr. N. E. Rider acted in a part-time capacity as a consultant to the Geneva-based planning staff for the Global Atmospheric Research Programme. His specific task was to assess the possibilities of the special observing systems for use in the tropics during the First GARP Global Experiment and assist in their planning.

The scientific research of the Office was reviewed by the Meteorological Research Committee and its subcommittees during the course of nine meetings. The Committee also advises on a number of small university research projects which are directly supported by the Meteorological Office in addition to the contracts placed in connection with the study of the effects of aircraft on the stratosphere; these number four together with seven placed through the Gassiot Committee of the Royal Society.

During the year six members of university staffs worked in the Office as consultants for short periods. Also eight research scientists from overseas carried out research in the Meteorological Office for extended periods during which they were supported by their home institutions or international fellowships.

Library, Publications, Archives and Cartographic Section

The Meteorological Office Headquarters Library serves the information needs of the staff of the Meteorological Office and also functions as the National Meteorological Library, about one-third of all loans being made to universities, schools, commercial and industrial firms, and the general public.

Comprehensive author and subject catalogues are maintained of the stock of over 120 000 volumes. The subject catalogue is arranged in several hundred sections by the Universal Decimal Classification, and reference to a book or journal article often appears in more than one section. Other useful guides to the collections are climatological, synoptic-climatological, and upper-air bibliographies which are arranged on a geographical basis.

A monthly accessions list is printed for the Library by Her Majesty's Stationery Office (HMSO) with minimum delay and is distributed to 300 official and learned bodies at home and abroad. Each list usually contains about 700 entries, and is primarily intended as a 'current-awareness' guide for research staff.

Some figures representative of the work of the Library are given in Table XVI on page 105.

The Editing Section remained responsible for the preparation for printing of most official publications of the Office and co-operated closely with HMSO

in the maintenance of publishing standards. It was also responsible for editing and producing the bilingual Programme and Abstracts of the COVOS/COMESA Anglo-French symposium at Oxford.

Works published during the year are listed in Appendix III; these include the *Meteorological Magazine*, a monthly journal containing short scientific articles, reviews, and items of interest to meteorologists everywhere.

Meteorological observations in manuscript and other original documents and records are kept, in accordance with the Public Records Act of 1958, in special repositories (Archives) in Bracknell, Edinburgh and Belfast. The material in these Archives is consulted by a large number of people, both inside and outside the Office; during the year, for instance, over 2000 inquiries were made at Bracknell.

The Cartographic Section prepares diagrams for Meteorological Office publications, for internal memoranda and for papers published in scientific journals by Meteorological Office staff. The preparation of data-entry forms, exhibition displays, lecture and training viewfoils and slides is undertaken together with the reprographic action necessary for printing these and other miscellaneous items.

Some statistics showing the extent of the work carried out by the Cartographic Section are given in Table XVI.

Professional Training

Professional training in the Meteorological Office centres upon the Meteorological Office College at Shinfield Park, near Reading, and the Technical Training School at Beaufort Park, close to Bracknell. The small radiosonde training centre at Hemsby was closed down early in the year as a consequence of the progressive automation of the upper-air sounding work. A smaller upper-air training facility was established in the Observational Requirements and Practices Branch at Beaufort Park, so that it remains possible for radiosonde training to be given within the Office, including training for members of overseas services using less automated procedures.

The Meteorological Office College has been located at Shinfield Park since 1971 when it assumed the training functions of the Training School at Stanmore. It was designed to be fully residential with study–bedrooms available for 110 students. However, with steady growth in the training demand it became necessary for the first time in October this year for some students to live out in private accommodation. The classrooms and lecture theatres at the College are contained within two principal buildings. The first has seven spacious classrooms equipped with light-tables and projection facilities. In these practical instruction in weather analysis and forecasting takes place. Five of the classrooms are grouped around a central instruments lobby from which the weather elements are continuously monitored; as well as the more usual meteorological quantities, global and diffuse solar radiation, net radiation flux, cloud base, and the profile of temperature in the vertical from one metre below to one metre above ground, are measured. Within the same building are a lecture theatre seating 52, the technical library, communications and chart duplicating rooms and the administrative offices. The second instructional building is devoted largely to training in weather observing, the

preparation of weather messages and charts and in the use of meteorological instruments. In addition to the classrooms, workshop, communications room, and a students' common room there is a small lecture theatre, an instruments laboratory and a cinema, seating 94. The cinema is well equipped for lecturing as well as for the showing of the instructional films which are an important part of the curriculum. The communications facilities allow for the simulation of the working conditions of an operational forecasting office. The College is served by teleprinter and facsimile networks based on the Regional Telecommunications Hub at Bracknell and on London/Heathrow Airport. Satellite television and infra-red pictures are received through a direct link with the APT reception station at Beaufort Park. Radio-facsimile reception enables surface and upper-air analyses to be obtained from all parts of the world.

The extensive grounds of the College allow room for the field work which has formed an important part of the Scientific Officers' and other courses in recent years. There are also excellent social facilities.

The programme of courses at Shinfield Park is determined by the Meteorological Office Training Board, under the chairmanship of the Director-General. The year saw the successful conclusion in March of the largest Scientific Officers' Course ever to be held. The 24 post-graduate members, including 3 from overseas, received training over a period of six months. This included grounding in physical, dynamical and synoptic meteorology followed by more-advanced lectures in specialized fields which took them to the limits of present knowledge in certain areas, notably in cloud physics, numerical weather prediction, and the physics and dynamics of the stratosphere. Since the majority of those taking the course were new entrants, the programme also included many lectures and visits designed to familiarize them thoroughly with the work of the Office, and each spent three or four weeks at selected airports and weather centres, gaining experience at first hand of the requirements of the many interests which the Office serves. Another full Scientific Officers' Course commenced in October.

The first of a new series of courses designed for post-graduate entrants going directly into the applied meteorology or forecasting fields ended in January. Known as the Applied Meteorology Course, this was a most successful innovation and in September the second of the series commenced with 32 members. The content of the Applied Meteorology Course parallels that of the Scientific Officers' Course which is intended mainly for those going into the research branches, but it is shorter and more closely geared to the immediate needs of the services branches.

The Initial Forecasting Course, of which only one is now held each year, was well attended and included a high proportion of students from overseas. It is entered with 'A' levels in Mathematics and Physics. While it has a strong vocational orientation it also contains a sound introduction to meteorological theory and it has become an integral part of the University of Reading Sandwich Course. The Sandwich Course consists of alternating academic and industrial periods, the latter in this case being spent in the Meteorological Office. It leads to an honours degree in Meteorology and takes three and a half years to complete. The Sandwich Course is particularly attractive to overseas students who are able to obtain in a single course both a good graduate qualification and training in the practical aspects of weather forecasting. Co-operation with the Geophysics Department of the University of Reading was taken a

stage further in 1974 when several overseas M.Sc. candidates took one or other of the Meteorological Office College courses as part of their preparatory studies.

New entrants to the Meteorological Office with 'O' or 'A' levels in Mathematics and Physics receive one of two 4-week courses according to the field in which they are expected to work. After additional on-the-job training and about two years' practical experience, they return to the College for an Advanced Synoptic Assistants' Course. From the commencement of the 1974–75 academic year, formal certificates have been issued to staff successfully completing the full programme of training. Certificates will also be issued, at the request of the staff union, the Institution of Professional Civil Servants, to forecasters becoming qualified at the conclusion of the Initial and Advanced Forecasting Courses, and of the Applied Meteorology Course.

Other major courses at the Meteorological Office College are of shorter duration and are intended for staff at later stages of their careers. They include the Advanced Forecasting Course (7 weeks), the Extension Course (4 weeks) and the Senior Meteorologists' Course (3 weeks). Developments in meteorology as a science and as a profession are taking place at such a pace that refresher courses have become necessary for staff not themselves working directly in the research field, at intervals of from 5 to 10 years. The SO (Supervisors') Course was introduced in 1973 for staff with considerable experience as Assistant Scientific Officers and newly promoted to fill supervisory posts. Its scope, as described in the 1973 *Report*, was further expanded and it has settled down to fill a valuable training role. More specialized courses including the Meteorological Statistics Course, the Tropical Meteorology Course and the Mediterranean Meteorology Course have continued to be well attended. A number of one-week courses have been provided for Air Traffic Controllers required to make weather observations at aerodromes, and for observers who are not members of the Meteorological Office but who, coming from many walks of life, man the Auxiliary Reporting and Climatological Stations. Inquiries concerning courses should be addressed to the Principal, Meteorological Office College, Shinfield Park, Reading RG2 9AU.

Those joining the Meteorological Office as Assistant Scientific Officers are expected to take advantage of the part-time courses offered by Technical Colleges and Colleges of Further Education to improve their academic qualifications. The subjects of greatest interest are mathematics, physics and computer science which are taken at 'A' level or in the form of an H.N.C. course, usually in Applied Physics or in Mathematics, Statistics and Computing. The first year was completed at the Reading College of Technology of a 2-year 'block-release' H.N.C. course provided to help Meteorological Office staff located at remote stations. The course consists of four 6-week periods of full-time study taken at intervals over 2 years. These are followed by a final examination. Thirteen staff members began the second year of the programme and a further 17 began first-year studies. Conveniently, the block-release students can reside at the Meteorological Office College. Another 290 members of the staff were released during the year for part-time study at colleges near to their offices. Others took advantage of the more limited concessions available under a Further Education Scheme and in particular, Mr J. C. McDougall, an Officer stationed at RAF Lossiemouth in Scotland, became the first member of the Office to gain a degree in the Open University.

Six trainee technicians completed an electronics course at RAF Sealand and later attended the six-months' Technicians' Course at the Technical Training School of the Meteorological Office at Beaufort Park.

Table XVII contains details of all courses completed in 1974 at Meteorological Office Training Establishments. In addition to those listed in the Table, 14 overseas students taking degree courses in the Department of Geophysics of the University of Reading were sponsored by the Meteorological Office as a contribution to the Voluntary Assistance Programme of the World Meteorological Organization.

J. S. SAWYER
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library

Publications received: Daily weather reports	13 697
Books, journals etc.	7 784
Slides and photographs	698
Individual books, pamphlets, articles etc. classified and catalogued	8 335
Publications lent (excluding internal 48-hour loans)	
Daily weather reports	10 074
Books, journals etc.	18 378
Slides and photographs	5 622
Number of exchange agreements	377
Number of pages translated by Library translators	1 233
Russian 941, German 246, French 46	
Number of pages translated by freelance translators	215
Dutch 64, Japanese 62, French 61, Italian 14, Serbo-Croat 5, Polish 4, Spanish 4, Russian 1	

Archives

Number of loans	1 885

Cartographic Section

Number of diagrams, maps and charts completed during year	2 689
Number of reprographic jobs during year	230

TABLE XVII—TRAINING

The following figures give details of courses completed during 1974 at the Meteorological Office training establishments at Shinfield Park, Hemsby and Beaufort Park.

	Number of courses	Length of course in weeks	Number of students
Scientific Officers	1	28	24
Applied Meteorology	1	22	25
Initial Forecasting	1	18	33
Advanced Forecasting	4	7	32
Extension Course	2	4	20
Senior Meteorologists	1	3	23
Meteorological Statistics	1	4	10
Tropical Meteorology	2	3	21
Mediterranean Meteorology	2	3	11
SO (Supervisors)	4	4	29
Auxiliary and Co-operating Observers	7	1	82
Basic Meteorology (Assistant level)	2	4	14
Initial Assistant	9	4	91
Advanced Assistant	5	6	51
Air Traffic Control Officers	2	1	21
Radiosonde (Initial)	3	9	11*
Radiosonde (Advanced)	2	4	2*
Radiosonde (Refresher)	2	2	2*
Electronics	1	24	6
Technical Updating	12	2	33
Total			541

* At Hemsby until June 1974 thereafter at Beaufort Park.

Students from the following territories attended courses which terminated during 1974.

	Number of students
Afghanistan	1
Antigua	1
Bahrain	6
Belgium	5
Bolivia	1
British Honduras	1
Greece	1
Hong Kong	1
India	1
Iraq	1
Jamaica	1
Jersey	4
Jordan	1
Kenya	1
Kuwait	2
Liberia	2
Libya	2
Malaysia	6
Malta	1
Mauritius	1
Netherlands	2
Netherlands Antilles	1
Nigeria	1
St Helena	1
Seychelles	1
Sudan	3
Switzerland	1
Tanzania	1
Thailand	1
Turkey	1
Total	53

INTERNATIONAL CO-OPERATION

The main WMO* meetings in which staff of the Office took part were the Annual Session of the Executive Committee, three sessions of Technical Commissions, one session of the Regional Association VI (Europe), and the series of meetings to prepare a new agreement for weather ships. At the 26th Session of the Executive Committee in Geneva from 23 May to 13 June Dr B. J. Mason, Director-General, was assisted by Mr D. G. Harley, Assistant Director (International and Planning), and by Mr H. E. Davies, Secretary of the Meteorological Office. They were also advised by staff of the U.K. Permanent Mission in Geneva. The main matters dealt with were progress and planning of World Weather Watch and the Global Atmospheric Research Programme (GARP), the atmosphere as man's environment, and preparations for the World Congress in 1975.

At the 6th Session of the Commission for Basic Systems (formerly the Commission for Synoptic Meteorology) in Belgrade from 18 March to 5 April, the British delegation was led by Mr J. K. Bannon, Director of Services, and included Mr M. H. Freeman, Deputy Director (Forecasting), Mr E. J. Bell, Assistant Director (Telecommunications), Mr S. G. Cornford, Met O 6, and Instructor Lt Cdr P. G. Monk, Directorate of Naval Oceanography and Meteorology. Mr G. A. Corby, Deputy Director (Communications and Computers), gave one of the three scientific lectures to the meeting. The session was mainly concerned with the development of World Weather Watch. The introduction of new synoptic codes was deferred until the end of the decade.

The Commission for Aeronautical Meteorology met jointly with the ICAO 8th Air Navigation Conference and the subsequent MET Division Meeting in Montreal in April and May. Mr L. Sugden, Assistant Director (Public Services), and Mr C. H. Hinkel, Met O 7, took part. At the 6th Session in Washington, in October, of the Commission for Agricultural Meteorology the delegates were Mr R. Murray, Assistant Director (Agriculture and Hydrometeorology), and Mr C. V. Smith, Met O 8. Mr Murray was also a U.K. delegate at the Unesco/WMO Conference in Paris in September on the End of the International Hydrological Decade, and associated symposia.

Regional Association VI (Europe) held its 6th Session in Bucharest, from 17 to 25 September. Dr B. J. Mason led the delegation of Mr D. G. Harley and Mr D. McNaughton. The meeting concentrated on European aspects of World Weather Watch, especially on the observing system, including the supply of reports from weather ships and merchant ships in the Atlantic. The handling of climatological data was another subject of concern.

The Directors of a number of European Meteorological Services met informally in Oslo, Norway, on 6 and 7 May. Dr B. J. Mason, Director-General, took part, and while in Norway delivered a lecture by invitation at the University of Bergen.

In order to develop a new international agreement under the auspices of WMO for the operation of the North Atlantic Ocean Stations (weather ships) scheme, a Plenipotentiary Conference of States, mostly European, met in Geneva from 18 February to 1 March, and again from 4 to 15 November.

---

* A list of abbreviations used in this section, and their meanings, is given on page 114.

Mr N. Bradbury, Deputy Director (Observations), led the U.K. delegation of Mr L. Sugden, Captain G. A. White, Marine Superintendent, and financial and legal experts. During the adjournment of the Conference several countries had informal discussion in June at De Bilt, Netherlands, and an informal planning meeting was called by WMO in Geneva from 5 to 10 August to help resolve outstanding difficulties. The same team, apart from Mr Sugden, also took part in these meetings. A meeting of representatives of countries operating ships in the present scheme was held in London in October; Mr J. K. Bannon, Director of Services, Mr N. Bradbury and Captain G. A. White took part.

In the GARP Atlantic Tropical Experiment, which took place from June to September in the Atlantic south-west of Dakar, a large number of the staff were involved. Dr B. J. Mason chaired the Tropical Experiment Board which met in April in Geneva, when he was accompanied by Mr R. F. Jones, Deputy Director (Physical Research). In July Dr Mason visited Dakar, Senegal, the operational base for GATE, for several days for the inaugural ceremony and to visit and observe the operations. Almost all the staff of the Meteorological Research Flight were in Dakar during the experiment and Dr N. E. Rider, Assistant Director (High Atmosphere), visited the Operational Control Centre there. Other meetings and visits in preparation for and following up GATE are listed below.

The WMO Intergovernmental Panel for the First GARP Global Experiment met in Geneva in October when Mr G. A. Corby, Deputy Director (Communications and Computers), represented the United Kingdom.

The Interim Committee, to govern the European Centre for Medium-range Weather Forecasts until its Convention should come into force, met on three occasions during the year. Dr B. J. Mason attended the January meeting and Mr G. A. Corby the October one. Mr E. Slater, Met O 10, represented the United Kingdom in the Finance Sub-committee when it met in Bracknell in May. Mr E. Knighting and, after his retirement, Mr F. H. Bushby, Deputy Directors (Dynamical Research), were members of the Scientific Sub-committee which met three times in Brussels. After the Acting Director of the Centre, Dr A. Wiin-Nielsen, took up post in the Centre's temporary offices in Fitzwilliam House in Bracknell, such initial help as he needed was given until the Centre had staff who could take over. In November the Director and Dr Bengtsson addressed Office staff on the plans of the Centre.

The European projects under the scheme for Co-operation in Science and Technology (COST) on oceanography and meteorology are still being developed at the technical level. Mr M. J. Blackwell, Assistant Director (Operational Instrumentation), and Mr G. J. Day, Met O 16, attended the three meetings of the COST Technical Committee on the projects. The Meteorological Office College, Shinfield Park, was used for two sessions of the Sub-Group on Automatic Weather Stations, with Mr G. J. Day as Chairman, assisted by Mr K. J. T. Sands, Met O 16. Other attendances at COST meetings are listed below.

The development of the European meteorological satellite METEOSAT, supported through the European Space Agency by eight European countries, involved much activity. Dr B. J. Mason, Director-General, met other Directors of Meteorological Services involved in Paris in February and, with Dr K. H. Stewart, Deputy Director (Physical Research), at Lannion, France in October. Of the 5 meetings of the METEOSAT Programme Board in Paris Dr Mason attended 4 and Dr K. H. Stewart 3. Dr Stewart also took part in 5 meetings

of the METEOSAT Scientific and Technical Advisory Group (STAG) in Paris and one on Critical Design Review at Toulouse. Mr D. E. Miller, Met O 19, headed the working group on METEOSAT software and had several meetings on the subject in Darmstadt and Paris, besides attending the Programme Board and STAG meetings when necessary.

Several visits to the Meteorological Services of other countries were made. In April Mr M. E. Robson, Met O 1, visited Bauerfield, New Hebrides, to conduct a technical inspection of the WWW upper-air station there which is jointly financed by France and the United Kingdom. Also in April Mr P. Menmuir, Met O 12, spent a month in Warsaw as an expert on computer-controlled data-plotting. In September Mr J. M. Craddock, Met O 13, visited the Hungarian Meteorological Service for lectures and consultations on data banks and data processing. The last two of these visits were made by arrangement with WMO. Other visits to Meteorological Services are included in the lists below.

Other WMO meetings, or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, were as follows:

Subject	*Place and date*	*Attended by*
JOC for GARP—9th Session	Canberra January	Mr J. S. Sawyer, Director of Research
CAeM Working Group Area Forecast System	Geneva January	Mr L. R. Nixon (Met O 7)
Informal Planning Meeting on the Further Development of the WWW GOS	Geneva January	Mr L. S. Clarkson, Assistant Director (Observational Requirements and Practices)
U.S./U.K. Bilateral Meeting on Development of Digitized Facsimile for Application within the WWW	Washington January	Mr. C. E. Goodison (Met O 5) Mr R. J. Sowden (Met O 5)
Meeting with Joint Planning Staff for GARP	Geneva February	Dr N. E. Rider, Assistant Director (High Atmosphere)
Bilateral U.K./Norway Co-ordination Meeting on Telecommunications Facilities between Bracknell RTH and Oslo NMC	Bracknell February	Mr E. J. Bell, Assistant Director (Telecommunications) Mr D. McNaughton (Met O 5)
3rd Informal Planning Meeting on GATE Data Management	Washington February	Mr C. H. Jarvis (Met O 12)
VAP Major Donors' Meeting	Singapore February	Mr G. Needham (Met O 17)
GATE Workshop	Boulder, Colorado March	Mr J. M. Nicholls (MRF)
Meeting to Discuss Technical Problems and their Solution Connected with the Use of LOCATE Equipment in GATE	New York April	Dr P. Ryder (Met O 15)
(Irish) National Committee on Geodesy and Geophysics	Dublin April	Mr T. A. M. Bradbury (Met O 7)
International Comparison of Pyranometers Prior to GATE	Miami April	Mr R. H. Collingbourne (Met O 1)
Final Planning Meeting on GATE Telecommunications Organization	Geneva April	Mr E. J. Bell, Assistant Director (Telecommunications)
CMM Working Group on Marine Meteorological Services Systems	Geneva April	Capt G. A. White (Marine Superintendent)
4th Co-ordination Meeting on Geostationary Satellites	Geneva May	Dr N. E. Rider, Assistant Director (High Atmosphere)

Subject	*Place and date*	*Attended by*
WMO Sponsored Meeting on Intercomparison of Total Ozone Measuring Instruments	Belsk, Poland June–July	Mr J. H. Convery (Met O 19)
CoSAMC Working Group on Guides and Technical Regulations	Geneva June	Mr J. S. Hopkins (Met O 3)
NCAR Workshop on Fine Mesh Limited Area Numerical Weather Prediction Models	Boulder, Colorado July	Mr D. E. Jones (Met O 11)
WMO Meeting on Physical Basis of Climate	Stockholm July–August	Dr R. Hide (Head of Met O 21)
Bilateral U.K./Netherlands Co-Ordination Meetings on Telecommunications Facilities between Bracknell RTH and Netherlands Centres	Hilversum/ De Bilt July–August	Mr D. McNaughton (Met O 5)
WMO International Seminar on Hydrological Network Design	Newcastle-upon-Tyne August	Mr R. J. Shearman (Met O 8)
International Symposium on Spectral Methods in Numerical Weather Prediction	Copenhagen August	Mr F. H. Bushby, Deputy Director (Dynamical Research) Dr D. M. Burridge (Met O 11) Dr R. A. Plumb (Met O 21)
10th Session of the GARP Working Group on Numerical Experimentation	Copenhagen August	Mr F. H. Bushby, Deputy Director (Dynamical Research)
Bilateral U.K./Belgium Co-ordination Meeting on Telecommunication Facilities between Bracknell RTH and Brussels NMC	Bracknell August	Mr D. McNaughton (Met O 5) Mr R. Ross (Met O 5)
Participation in the GATE Experiment	Aboard HMS *Hecla*	Dr N. Thompson (Met O 14) Mr D. R. Davies (Met O 14) Mr I. Winters (Met O 14) Mr J. B. Whitlock (Met O 14)
IMCO Sub-Committee on Safety of Fishing Vessels—16th Session	London September	Mr H. C. Shellard (Met O 3) (WMO representative)
Co-ordination Meeting with WMO Secretariat on Iceland VAP Telecommunication Project	Geneva September	Mr E. J. Bell, Assistant Director (Telecommunications) Mr J. D. Lunn (Met O 5)
3rd Session of EC Panel/CAS Working Group on Cloud Physics and Weather Modification	Toronto October–November	Mr P. Goldsmith, Assistant Director (Cloud Physics)
WMO Informal Planning Meeting on Implementation of the Iceland VAP Telecommunication Project	London November	Mr C. E. Goodison (Met O 5) Mr J. D. Lunn (Met O 5)
WMO Co-ordination Meeting on Implementation of the RTHs in Regional Association VI (Europe)	Geneva December	Mr E. J. Bell, Assistant Director (Telecommunications)

Attendances, not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad were as follows:

Subject	*Place and date*	*Attended by*
International Conference on Finite Element Methods in Flow Problems	Swansea January	Mr M. J. P. Cullen (Met O 20)
Meteorological Panel (Panel XII) of NATO Group AC/225—10th Meeting	Brussels January	Mr K. Bryant (Met O 6)
OECD Meeting on Aircraft Measurements of Air Pollution	Bilthoven, The Netherlands January	Dr D. A. Johnson (MRF)

Subject	*Place and date*	*Attended by*
MJS (1977) Imaging Science Team Meetings	Pasadena, Calif. January–February Cambridge, Mass. April Madison, Wisconsin June Flagstaff, Arizona September Santa Monica, Calif. October	Dr G. E. Hunt (Met O 20)
NMC Washington to discuss Medium Range Forecasting Techniques	Washington January	Mr A. G. Matthewman (Met O 2)
3rd Survey Conference on Climatic Impact Assessment Programme	Boston, Mass. February–March	
Massachusetts Institute of Technology	Cambridge, Mass. March	
Geophysical Fluid Dynamics Laboratory	Princeton, N. J. March	Mr R. L. Newson (Met O 20)
National Meteorological Center	Suitland, Maryland March	
Co-ordination Meeting on NATO Meteorological Support	Wahn February	Mr G. A. Cowling (Met O 6)
NATO Special Programme Panel on Air–Sea Interaction	Brussels February, November Hamburg July	Mr J. S. Sawyer, Director of Research
NATO Co-ordination Group for Tactical Weather Network–19th Meeting	Brussels March	Mr W. G. Durbin (Met O 6) Mr G. A. Cowling (Met O 6)
NATO MCMG Working Groups on Weather Plans and Communications —39th Meeting	Lisbon March	Mr J. C. Gordon (Met O 6) Mr C. E. Goodison (Met O 5)
NATO MCMG Working Groups on Weather Plans and Communications —40th Meeting	Oslo October	Mr J. C. Gordon (Met O 6) Mr C. E. Goodison (Met O 5)
5th Conference on Weather Forecasting and Analysis—American Meteorological Society	St Louis, Missouri March	Mr T. H. Kirk (Met O 2)
NCAR	Boulder, Colorado	Mr T. H. Kirk (Met O 2)
Techniques Development Laboratory	Silver Spring, Maryland	
National Meteorological Center & National Environmental Satellite Center	Suitland, Maryland March	
COST Project 43—Faeroes/Shetland Regional Sub-group	London March	Mr G. J. Day (Met O 16)
COST Project 72—Sub-group on Radiosondes	Trappes, France March,	Mr A. H. Hooper (Met O 1)
	September, October	Dr D. N. Axford (Met O 16)
Working Group on JONSIS	Lowestoft March	Mr M. J. Blackwell, Assistant Director (Operational Instrumentation)
Division of Planetary Sciences, American Astronomical Society, Annual Meeting	Palo Alto, Calif. April	Dr G. E. Hunt (Met O 20)
AFCENT Meteorological Committee—22nd Meeting	Brunssum, The Netherlands April	Mr W. G. Durbin (Met O 6) Mr G. A. Cowling (Met O 6)

Subject	*Place and date*	*Attended by*
AFCENT Meteorological Sub-Group on International Exercise	Rheindahlen April	Mr G. A. Cowling (Met O 6)
	September–October	Mr G. A. Cowling (Met O 6) Mr N. Holdsworth (Met O 6)
Technical and Specifications Discussion TIROS N	Washington April	Dr K. H. Stewart (Met O 19) Mr G. P. Carruthers (Met O 19)
Working Group on Environmental Matters Affecting Offshore Installations	London April	Mr H. C. Shellard (Met O 3)
Co-ordination Meeting for NATO International Exercise	London May	Mr K. Bryant (Met O 6)
NATO Military Agency for Standardization of Operational Procedures, Inter-Service Working Party	Brussels May	Mr G. A. Samuel (Met O 6)
COST Project 72—Sub-Committee	Hamburg May	Mr G. J. Day (Met O 16) Mr G. A. Clift (Met O 16)
Discussion with Dr C. Pastre of Météorologie Nationale on Sea Surface Temperature Data from Satellites	Paris May	Mr P. R. S. Salter (Met O 19)
Informal Meeting of some European States	De Bilt June	Mr N. Bradbury, Deputy Director (Observational Services)
ICSU Committee on Space Research (COSPAR)	São Paulo, Brazil June	Dr N. E. Rider, Assistant Director (High Atmosphere)
International Seminar on Effects of Space Environment on Materials	Toulouse June	Mr G. P. Carruthers (Met O 19)
NASA/ESRO Pioneer Jupiter Orbiter Meetings	Moffett Field, Calif. June, November Paris September Munich October	Dr G. E. Hunt (Met O 20)
European Mechanics Colloquium No. 51 on Small-scale Mixing in Stably Stratified Fluids	Cambridge June	Dr D. J. Carson (Met O 20) Dr C. J. Readings (Met O 14)
International Association for Mathematical Geophysics Symposium	Cambridge June	Dr R. Hide (Head of Met O 21)
NATO MCMG—31st Meeting	Hamburg June	Mr E. Evans, Assistant Director (Defence Services) Mr J. C. Gordon (Met O 6)
ICAO Informal Meteorological Meeting on IGA	Paris June	Mr C. H. Hinkel (Met O 7)
5th Meeting of the Expert Panel on Air Pollution Modelling	Risø, Denmark June	Dr F. B. Smith, Assistant Director (Boundary Layer)
Discussions with AFCRL Concerning the Minnesota Experiment	Bedford, Mass. June	Dr C. J. Readings (Met O 14)
Meeting to Discuss the Organization of the European Daily Weather Report	Offenbach July	Mr G. R. R. Benwell, Assistant Director (Central Forecasting)
Informal Meeting on Stratospheric Sudden Warmings	Wallops I., Va. and Washington August	Mr N. R. Watson (Met O 19)
Familiarization Visit to Inspect Telecommunication and Electronic Systems and Installations, Charles de Gaulle Airport	Paris August	Mr E. J. Bell, Assistant Director (Telecommunications)
5th International Conference on Atmospheric Electricity	Garmisch September	Dr P. Ryder (Met O 15)

Subject	*Place and date*	*Attended by*
2nd COVOS/COMESA Symposium	Oxford September	Mr P. Graystone, Assistant Director (Forecasting Research) Mr P. Goldsmith, Assistant Director (Cloud Physics) Dr E. L. Simmons (Met O 15) Dr J. S. Foot (Met O 15) Dr R. J. Murgatroyd (Met O 20) Dr A. F. Tuck (Met O 20) Dr P. E. Francis (Met O 20) Dr S. R. Mattingly (Met O 20) Mr R. L. Newson (Met O 20) Mr R. E. W. Pettifer (Met O 19)
Technical Review of Stratospheric Sounding Unit/TIROS N Satellite Progress	Washington September	Dr D. Pick (Met O 19) Mr G. P. Carruthers (Met O 19) Mr M. J. Kerley (Met O 19)
1st Meeting of Advisory Group for the Co-ordination in Europe on the Reception and Evaluation of Information from Satellites	Zurich September	Mr B. R. May (Met O 19)
European Geophysical Society Meeting	Trieste September	Mr C. Temperton (Met O 20)
International Conference on Computational Methods in Non-linear Mechanics	Austin, Texas September	Mr M. J. P. Cullen (Met O 20)
CENTO Regional Meteorological Group—4th Meeting	Ankara September	Mr J. C. Gordon (Met O 6)
Meteorological Panel (Panel XII) of NATO Group AC/225—11th Meeting	Brussels September	Mr K. Bryant (Met O 6)
European Symposium on Offshore Data Acquisition Systems	Southampton September	Mr G. J. Day (Met O 16) Mr D. J. Painting (Met O 16)
National Center for Atmospheric Research	Boulder, Colorado	Mr M. J. P. Cullen (Met O 20)
Geophysical Fluid Dynamics Laboratory	Princeton, N. J.	
Massachusetts Institute of Technology	Boston, Mass. September–October	
Anglo-French Discussions on Analysis of Concorde Data	Paris October	Mr J. Briggs, Assistant Director (Special Investigations) Mr R. N. Hardy (Met O 9)
Atmospheric Sciences Laboratory, Artillery Meteorological Comparisons	White Sands, N.M. October–November	Dr P. W. White (Met O 11)
SHAPE Meteorological Committee—17th Meeting	Oslo October	Mr J. C. Gordon (Met O 6) Mr C. E. Goodison (Met O 5)
Liaison with French Meteorological Service	Trappes, France October	Mr K. J. T. Sands (Met O 16)
AFCENT Meteorological Sub-Group—14th Meeting	Rheindahlen November	Mr W. G. Durbin (Met O 6) Mr G. A. Cowling (Met O 6) Mr W. Hyde (Met O 6)
Unesco assignment	Alexandria, Egypt December	Mr A. F. Jenkinson (Met O 13)

The following staff were released by the Office during 1974 for service with international and other organizations:

Dr K. A. Browning	Senior Principal Scientific Officer	NCAR, U.S.A.
Mr D. B. Shaw	Senior Scientific Officer	WMO/UNDP, Cairo
Mr M. W. Stubbs	Principal Scientific Officer	WMO, Geneva
Mr K. E. Woodley	Higher Scientific Officer	WMO, Geneva
Mr J. Ballentine	Higher Scientific Officer	IMCO, Persian Gulf
Mr W. E. Hughes	Scientific Officer	IAL, Bahrain
Mr W. K. Young	Scientific Officer	WMO, Geneva
Mr D. J. Clark	Senior Scientific Officer	ECMWF, Bracknell
Mr R. Greener	Telecommunications Technical Officer III	New Hebrides (on secondment)

Returning from secondment appointments overseas were:

Mr E. P. Ward	Telecommunications Technical Officer II	Falkland Islands
Mr H. S. G. Rich	Scientific Officer	New Hebrides
Mr H. Burton	Telecommunications Technical Officer III	New Hebrides

LIST OF ABBREVIATIONS USED IN THIS SECTION

AFCENT	—	Allied Forces Central Europe
AFCRL	—	Air Force Cambridge (Massachusetts) Research Laboratories
CAeM	—	Commission for Aeronautical Meteorology
CAS	—	Commission for Atmospheric Sciences
CENTO	—	Central Treaty Organization
CMM	—	Commission for Marine Meteorology
COMESA	—	Committee on Meteorological Effects of Stratospheric Aircraft
CoSAMC	—	Commission for Special Application of Meteorology and Climatology
COSPAR	—	Committee for Space Research
COST	—	(European) Co-operation in Science and Technology
COVOS	—	Le Groupe d'Études sur les Conséquences des Vols Stratosphériques
ECMWF	—	European Centre for Medium-range Weather Forecasts
ESRO	—	European Space Research Organization
GARP	—	Global Atmospheric Research Programme
GATE	—	GARP Atlantic Tropical Experiment
GOS	—	Global Observing Systems
IAL	—	International Aeradio Ltd.
ICAO	—	International Civil Aviation Organization
ICSU	—	International Council of Scientific Unions
IGA	—	International General Aviation
IMCO	—	Inter-Governmental Maritime Consultative Organization
JOC	—	Joint Organizing Committee (for GARP)
JONSIS	—	Joint North Sea Information Systems
LOCATE	—	Loran/Omega Course and Track Equipment
MCMG	—	Military Committee Meteorological Group
MJS	—	Mariner, Jupiter, Saturn
NASA	—	National Aeronautics and Space Administration
NATO	—	North Atlantic Treaty Organization
NCAR	—	National Center for Atmospheric Research
NMC	—	National Meteorological Center

OECD	—	Organization for Economic Co-operation and Development
RTH	—	Regional Telecommunications Hub
SHAPE	—	Supreme Headquarters Allied Powers in Europe
UNDP	—	United Nations Development Programme
Unesco	—	United Nations Educational, Scientific and Cultural Organization
VAP	—	Voluntary Assistance Programme
WMO	—	World Meteorological Organization
WWW	—	World Weather Watch

STAFF

GENERAL

The names of the principal officers of the Meteorological Office are listed on pages xi–xiii and the organization of the Office is shown in the diagram on page xiv. At the end of 1974 the total number of posts of all grades was 3648, a decrease of 41 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary	1
Under Secretaries	2
Science Group	
Deputy Chief Scientific Officers	7
Senior Principal Scientific Officers	27
Principal Scientific Officers	105
Senior Scientific Officers	271
Higher Scientific Officers	551
Scientific Officers	508
Assistant Scientific Officers	1035
Administration Group	
Assistant Secretary	1
Principal	1
Executive Grades	26
Clerical Grades	145
Marine Staff	
Marine Superintendent	1
Nautical Officer Grades	10
Ocean Weather Ships and Base	
Officers and non-industrial grades	96
Crew	100
Professional Engineer Staff	
Superintending Engineer	1
Principal Professional and Technology Officer	1
Professional and Technology Officer Grade I	3
Professional and Technology Officer Grade II	4
Technical and Signals Grades	290
Typing and miscellaneous non-industrial grades	147
Industrial employees	100
Locally entered staff and employees overseas	135

Extra effort put into recruitment proved very worth while and by the end of the year the Office was up to strength; 53 graduates joined during the year and 152 new Assistant Scientific Officers including 7 part-timers. A significant decrease was noted in the turnover of Assistant Scientific Officers which is now down to 7 per cent.

Ten College-based sandwich-course students were accepted for their supervised industrial training periods and 11 undergraduates were employed during the long vacation. These students made a useful contribution to the work of the Office and several expressed a wish to join after graduation. Three post-graduate students were employed in the long vacation and 6 vacation consultants spent short periods in research branches during the summer. Four undergraduates were recruited as 'casual' Assistant Scientific Officers specifically for the GATE project and spent 11 weeks at the Operational Control Centre at Dakar.

HONOURS AND DISTINCTIONS

Mr H. C. Shellard was awarded the I.S.O. in the Queen's Birthday Honours List.

Dr B. J. Mason was given an Honorary Fellowship of the Imperial College of Science and Technology and was awarded the Glazebrook Medal by the Institute of Physics.

Dr K. A. Browning was awarded the 1974 Meisinger Award of the American Meteorological Society.

The L. G. Groves Memorial Prize for Meteorology was awarded to Dr C. J. Readings.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

AANENSEN, C. J. M., M.Sc.; The GATE aircraft plan. Section I. The aircraft operations plan. Geneva, World Meteorological Organization. GATE Report No. 11, 1974.

ADAMS, R. J., M.Sc.; A meteorological/entomological study. *Met Mag, London*, **103,** 1974, pp. 53–55.

ADAMS, R. J., *see* ROACH, W. T., ADAMS, R. J., GARLAND, J. A. and GOLDSMITH, P.,

ARMSTRONG, J. J.; Temperature differences between two ground-level sites and a roof site in Southampton. *Met Mag, London*, **103,** 1974, pp. 360–368.

BADER, M., M.Sc., GLOSTER, J., BROWNSCOMBE, J. L., Ph.D., and GOLDSMITH, P., M.A.; The production of sub-micron ice fragments by water droplets freezing in free fall or on accretion upon an ice surface. *Q J R Met Soc, London*, **100,** 1974, pp. 420–426.

BARRINGTON, C. R.; Prediction of warm days in July and August in London area. Comment on an article by FINCH, C. R. (*Weather, London*, **28,** 1973, p. 265). *Weather, London*, **29,** 1974, p. 117.

BELL, E. J., C. Eng., F.I.E.E.; Meteorological broadcasts. *Weather, London*, **29,** 1974, p. 78. Comment on an article by BLANCHARD, W. (*Weather, London*, **28,** 1973, pp. 339–344).

BENNETTS, D. A., Ph.D. and HOCKING, L. M.; Pressure-induced flows at low Rossby numbers. *Physics Fluids, New York*, **17,** 1974, pp. 1671–1676.

BENTLEY, A. N., DE JONGKHEERE, C. G. and MILLER, D. E., B.A.; Geometric albedo of the moon in the ultraviolet. *Astr J, Cambridge, Mass*, **79,** 1974, pp. 401–403.

BEYNON, A., *see* LOWNDES, C. A. S., BEYNON, A. and HAWSON, C. L.

BRIGGS, J., B.A. *in* DRUFUCA, G., BRIGGS, J. *et alii;* The statistics of rainfall rates and the design of communication systems. *J Rech Atmosph Obs Puy de Dôme, Clermont-Ferrand*, **8,** 1974, pp. 473–476.

BROWN, R., B.Sc.; New indices to locate clear-air turbulence. *Met Mag, London*, **102,** 1973, pp. 347–361.

BROWNING, K. A., Ph.D., D.I.C.; Mesoscale structure of rain systems in the British Isles. *J Met Soc Japan, Tokyo*, **52,** 1974, pp. 314–327.

BROWNING, K. A., Ph.D., D.I.C., HILL, F. F. and PARDOE, C. W., B.Sc.; Structure and mechanism of precipitation and the effect of orography in a wintertime warm sector. *Q J R Met Soc, London*, **100,** 1974, pp. 309–330.

BROWNING, K. A., Ph.D., D.I.C.; Towards an automated weather radar network. *Weather, London*, **29,** 1974, pp. 202–216.

BROWNSCOMBE, J. L., *see* BADER, M., GLOSTER, J., BROWNSCOMBE, J. L. and GOLDSMITH, P.

BROWNSCOMBE, J. L., Ph.D. and COLLINS, G. J., *in* MOSSOP, S. C., BROWNSCOMBE, J. L. and COLLINS, G. J.; The production of secondary ice particles during riming. *Q J R Met Soc, London*, **100,** 1974, pp. 427–436.

BROWNSCOMBE, J. L., Ph.D., PORTER, M. R. and GOLDSMITH, P., M.A.; A critical appraisal of the performance of the air sampling equipment used in the European air sampling network. *Spec Environ Rep Wld Met Org, Geneva*, No. 3, 1974, pp. 297–306.

BUTLER, H. E., *see* READINGS, C. J. and BUTLER, H. E.

CARSON, D. J., Ph.D. and SMITH, F. B., Ph.D.; A scheme for deriving day-time boundary-layer wind profiles. *Met Mag, London*, **103,** 1974, pp. 241–255.

CATTLE, H., Ph.D., D.I.C. and WESTON, K. J.; The determination of large-scale vertical motion by a modified isentropic technique. *Met Mag, London*, **103,** 1974, pp. 82–89.

CAUGHEY, S. J., Ph.D. and RAYMENT, R.; High-frequency temperature fluctuations in the atmospheric boundary layer. *Boundary Layer Met, Dordrecht*, **5,** 1974, pp. 489–503.

CAUGHEY, S. J., *see* READINGS, C. J. and CAUGHEY, S. J.

COCHRANE, J.; Meteorological observations in Hambledon vineyard in 1972. *Weather, London*, **29,** 1974, pp. 144–147.

COLGATE, M. G., *see* CRADDOCK, J. M. and COLGATE, M. G.

COLLINS, G. J., *see* BROWNSCOMBE, J. L. and COLLINS, G. J.

CORBY, G. A., B.Sc.; Global 5-level general circulation model. Rome, International Council of Scientific Unions, and Geneva, World Meteorological Organization. GARP Publications Series No. 14, Geneva, 1974, pp. 113–126.

CORNFORD, S. G., M.Sc.; Turbulence at medium and high flight levels. NATO, Advisory Group for Aerospace Research and Development. Flight in turbulence. *AGARD Conf Proc, London,* No. 140, 1973, pp. 1–14.

CRABTREE, J., B.A.; The surveyors' atmosphere. Land Hydrographic and Minerals Quarterly of the Royal Institution of Chartered Surveyors, London, **1,** No. 3, 1974, pp. 41–44.

CRADDOCK, J. M., M.A.; Global data-processing system. The storage, cataloguing and retrieval of meteorological information. Geneva, World Meteorological Organization. World Weather Watch Planning Report No. 34, Geneva, 1974.

CRADDOCK, J. M., M.A.; More thoughts on meteorology for amateurs. *Weather, London,* **29,** 1974, pp. 223–233.

CRADDOCK, J. M., M.A.; Phenological indicators and past climates. *Weather, London,* **29,** 1974, pp. 332–343.

CRADDOCK, J. M., M.A.; The place of statistics in meteorology. Manchester, Manchester Statistical Society, 1973.

CRADDOCK, J. M., M.A.; Report and commentary on a symposium on the assessment and verification of statistical and other software, held at Imperial College, London on 19 December 1973. *Met Mag, London,* **103,** 1974, pp. 305–313.

CRADDOCK, J. M., M.A. and COLGATE, M. G., B.Sc.; The use of eigenvectors for smoothing and prediction. *Bull Inst Maths and its Appl, London,* **10,** 1974, pp. 152–160.

CULLEN, M. J. P., B.A.; A finite element method for a non-linear initial value problem. *J Inst Maths and its Appl, London,* **13,** 1974, pp. 233–247.

CULLEN, M. J. P., B.A.; Integrations of the primitive equations on a sphere using the finite element method. *Q J R Met Soc, London,* **100,** 1974, pp. 555–562.

DAY, G. J., B.Sc., PAINTING, D. J. and SANDS, K. J. T.; The U.K. Meteorological Office data buoy programme. European Symposium on Offshore Data Acquisition Systems, London, 1974, pp. 117–134.

DAY, G. J., B.Sc., SANDS, K. J. T., and TONKINSON, B., B.Sc.; The Meteorological Office Weather Observing System (MOWOS) Mk 2. *Met Mag, London,* **103,** 1974, pp. 329–337.

ELSE, C. V.; The Meteorological Office Mk 5 wind system. *Met Mag, London,* **103,** 1974, pp. 130–140.

ELSE, C. V., PAINTING, D. J. and SANDS, K. J. T.; Electronics in meteorological instrumentation. *Proc Instn Elect Engrs, London,* **121,** 1974, p. 1201.

ENGLISH, E. J., *see* HARROLD, T. W., ENGLISH, E. J. and NICHOLASS, C. A.

EVANS, W., *see* HALL, B. A. and EVANS, W.

FINDLATER, J.; An extreme wind speed in the low-level jet-stream system of the western Indian Ocean. *Met Mag, London,* **103,** 1974, pp. 201–205.

FINDLATER, J.; The low-level cross-equatorial air current of the western Indian Ocean during the northern summer. *Weather, London,* **29,** 1974, pp. 411–416.

FINDLATER, J.; Some notes on the general circulation of the atmosphere and seasonal weather patterns of eastern Africa. Geneva, World Meteorological Organization. Agroclimatology of the Highlands of Eastern Africa (Proceedings of the Technical Conference, Nairobi, October 1973). Geneva, 1974, pp. 5–14.

FOLLAND, C. K., *see* MILES, K. and M. FOLLAND, C. K.

FOORD, H. V. [BERT]; Holiday weather. London, William Kimber, 1973.

FOOT, J. S., Ph.D., SIMMONS, E. L., M.A., Ph.D. and WHITTAKER, A. E.; Measurements of the swing of a balloon payload. *Met Mag, London,* **103,** 1974, pp. 110–115.

FORSDYKE, D., B.Sc.; A comparison of glasshouse crop water requirements derived from sunshine and solarimeter records at Efford Experimental Husbandry Farm. *ADAS Q Rev, London,* No. 12, 1974, pp. 139–144.

FORSDYKE, D., B.Sc.; Meteorological instrumentation and measurement. TAYLOR, ANGELA E. R. and MULLER, R. (editors); The effects of meteorological factors upon parasites. *Symp Brit Soc Parasitol, Oxford,* **12,** 1974, pp. 97–109.

GARROD, M. P. [M.]; A glider pilot's guide to wave forecasting—Part 2. *Sailpl Gliding, London,* **25,** 1974, pp. 28–29.

GEORGE, D. J.; An oceanic front off south-east Iceland. *Mar Obsr, London*, **44**, 1974, pp. 32–36.

GLOSTER, J., *see* BADER, M., GLOSTER, J., BROWNSCOMBE, J. L. and GOLDSMITH, P.

GOLDSMITH, P., M.A.; Pollution of the stratosphere and the SST. NATO Advisory Group for Aerospace Research and Development. *AGARD Advis Rep, Paris*, No. 55, 1974, pp. 52–53.

GOLDSMITH, P., *see* BADER, M., GLOSTER, J., BROWNSCOMBE, J. L. and GOLDSMITH, P.

GOLDSMITH, P., *see* BROWNSCOMBE, J. L., PORTER, M. R. and GOLDSMITH, P.

GOLDSMITH, P., *see* ROACH, W. T., ADAMS, R. J., GARLAND, J. A. and GOLDSMITH, P.

GRIFFITHS, C. I.; Tornado in south-east Essex on 7 August 1973. *Met Mag, London*, **103**, 1974, pp. 49–52.

HALL, B. A. and EVANS, W.; Contrails as an indication of horizontal wind-shear near a jet-stream. *Weather, London*, **29**, 1974, pp. 387–389.

HARDY, R. N., B.Sc.; Meteorological features affecting large aperture synthesis radio telescopes. *Nature, London*, **249**, 1974, pp. 431–433.

HARDY, R. N., B.Sc.; A note on the optimum averaging time of wind reports for aviation. *Met Mag, London*, **103**, 1974, pp. 99–105.

HARLEY, D. G., B.Sc.; The IMO/WMO centenary celebrations. *Met Mag, London*, **103**, 1974, pp. 1–2.

HARROLD, T. W., Ph.D., D.I.C.; Ground clutter observed in the Dee Weather Radar Project. *Met Mag, London*, **103**, 1974, pp. 140–141.

HARROLD, T. W., Ph.D., D.I.C.; The use of weather-radar data in communication engineering. *Met Mag, London*, **103**, 1974, pp. 125–129.

HARROLD, T. W., Ph.D., D.I.C. and AUSTIN, P. M.; The structure of precipitation systems—a review. *J Rech Atmosph Obs Puy de Dôme, Clermont-Ferrand*, **8**, 1974, pp. 41–57.

HARROLD, T. W., Ph.D., D.I.C., ENGLISH, E. J., B.Sc. and NICHOLASS, C. A., B.Sc.; The accuracy of radar-derived rainfall measurements in hilly terrain. *Q J R Met Soc, London*, **100**, 1974, pp. 331–350.

HARROLD, T. W., Ph.D., D.I.C. *in* ROGERS, R. R., HARROLD, T. W. *et alii*; The mesoscale structure of precipitation and space diversity. *J Rech Atmosph Obs Puy de Dôme, Clermont-Ferrand*, **8**, 1974, pp. 485–490.

HAWSON, C. L., B.A.; Five-year climatic trend in the northern hemisphere. Comment on an article by STARR, V. P. and OORT, A. H., (*Nature, London*, **242**, 1973, pp. 310–313). *Nature, London*, **249**, 1974, pp. 540–541.

HAWSON, C. L., *see* LOWNDES, C. A. S., BEYNON, A. and HAWSON, C. L.

HEALEY, P. G., *see* PETTIFER, R. E. W. and HEALEY, P. G.

HIDE, R., Sc.D., F.R.S.; Jupiter and Saturn. *Proc R Soc, London*, A, **336**, 1974, pp. 63–84.

HILL, F. F., *see* BROWNING, D. A., HILL, F. F. and PARDOE, C. W.

HILL, F. F. and LEWIS, R. P. W., M.A., M.Sc.; The distribution and frequency of high cumulonimbus tops near Singapore as measured by 10-centimetre radar. *Met Mag, London*, **103**, 1974, pp. 29–48 and 61–70.

HOUGHTON, D. M., M.Sc., D.I.C.; Are you weatherwise? *Yachting World, London*, **126**, 1974, pp. 152–153.

HOUGHTON, D. M., M.Sc., D.I.C.; Weather forecasts. London, Royal Yachting Association, R.Y.A. Publication G5/74, 1974.

HUNT, G. E., Ph.D., F.I.M.A.; The atmospheres of Jupiter and Saturn. *Endeavour, London*, **33**, 1974, pp. 23–28.

HUNT, G. E., Ph.D., F.I.M.A.; A new look to the Martian atmosphere. *Proc R Soc, London*, A, **341**, 1974, pp. 317–330.

HUNT, G. E., Ph.D., F.I.M.A.; Pioneer 10: the preliminary results. *New Scientist, London*, **61**, 1974, pp. 125–127.

HUNT, G. E. [G.], Ph.D., F.I.M.A.; The riddle of Titan's gas. *New Scientist, London*, **64**, 1974, pp. 429–430.

HUNT, G. E., Ph.D., F.I.M.A. and BERGSTRALH, J. T.; Structure of the visible Jovian clouds. *Nature, London*, **249**, 1974, pp. 635–637.

JACKSON, M. C., M.Sc.; Largest two-hour falls of rain in the British Isles. *Weather, London*, **29**, 1974, pp. 71–73.

JOHNSON, D. A., Ph.D. and ATKINS, D. H. F.; A technique for measurement of sulphur dioxide and sulphate concentrations from an aircraft. *Spec Environ Rep, Wld Met Org, Geneva*, No. 3, 1974, pp. 216–222.

JONAS, P. R., *see* MASON, B. J. and JONAS, P. R.

JONAS, P. R., Ph.D., D.I.C. and MASON, B. J., C.B., D.Sc., F.R.S.; The evolution of droplet spectra by condensation and coalescence in cumulus clouds. *Q J R Met Soc, London*, **100**, 1974, pp. 286–295.

DE JONCKHEERE, C. G., *see* BENTLEY, A. N., DE JONCKHEERE, C. G. and MILLER, D. E.

DE JONCKHEERE, C. G. and MILLER, D. E., B.A.; A measurement of the ozone concentration from 65 to 75 km at night. *Planet Space Sci, London*, **22**, 1974, pp. 497–499.

JONES, J. I. P.; A liquid suspension, high sensitivity anemograph. Comment on a paper by CIVITANO, L. and LONGHETTO, A. (*Atmos Environ, Oxford*, **7**, 1973, pp. 1285–1289). *Atmos Environ, Oxford*, **8**, 1974, p. 673.

KEMP, B.; Radar observation of a secondary depression approaching Wales. *Weather, London*, **29**, 1974, pp. 272–273.

KEMP, B., *see* STARR, J. R. and KEMP, B.

KIRK, T. H., B.Sc.; The use of numerical forecasts. *Met Mag, London*, **103**, 1974, pp. 14–20.

LANKESTER, J. D., *see* MURRAY, R. and LANKESTER, J. D.

LEE, M. F., B.Sc.; Cumulus cloud from a stubble fire. *Weather, London*, **29**, 1974, pp. 102–103.

LEWIS, R. P. W., *see* HILL, F. F. and LEWIS, R. P. W.

LONG, C., B.Sc.; The oldest European weather diary? *Weather, London*, **29**, 1974, pp. 233–237.

LOWNDES, C. A. S., BEYNON, A., B.Sc. and HAWSON, C. L., B.A.; An assessment of the usefulness of some snow predictors. *Met Mag, London*, **103**, 1974, pp. 341–358.

MASON, B. J., C.B., D.Sc., F.R.S.; The contribution of satellites to the exploration of the global atmosphere and to the improvement of weather forecasting. *Met Mag, London*, **103**, 1974, pp. 181–201.

MASON, B. J., C.B., D.Sc., F.R.S.; The evolution of meteorology as a science and a technology. Lisbon, Serviço Meteorológico Nacional. Symposium on the Meteorological Services facing the progress in the field of meteorology. Present situation and prospects for the decade 1971–1980, Lisbon, October 1971. Lisbon, 1972.

MASON, B. J., *see* JONAS, P. R. and MASON, B. J.

MASON, B. J., C.B., D.Sc., F.R.S. and JONAS, P. R., Ph.D., D.I.C.; The evolution of droplet spectra and large droplets by condensation in cumulus clouds. *Q J R Met Soc, London*, **100**, 1974, pp. 23–38.

MENMUIR, P., B.Sc.; The automatic production of weather maps. *J Br Cartographic Soc, London*, **11**, 1974, pp. 12–18.

MILES, M. K., M.Sc.; An index of pack-ice severity off Newfoundland and its secular variation. *Met Mag, London*, **103**, 1974, pp. 121–125.

MILES, M. K., M.Sc.; The variation of annual mean surface pressure over the northern hemisphere during the double sunspot cycle. *Met Mag, London*, **103**, 1974, pp. 93–99.

MILES, M. K., M.Sc. and FOLLAND, C. K., B.Sc., Grad. Inst. P.; Changes in the latitude of the climatic zones of the northern hemisphere. *Nature, London*, **252**, 1974, p. 616.

MILLER, D. E., *see* BENTLEY, A. N., DE JONCKHEERE, C. G. and MILLER, D. E.

MILLER, D. E., *see* DE JONCKHEERE, C. G. and MILLER, D. E.

MURRAY, R., M.A.; Indicators of monthly mean temperature and rainfall for England and Wales based on antecedent monthly pressure anomalies over the northern hemisphere. *Met Mag, London*, **103**, 1974, pp. 70–73.

MURRAY, R., M.A. and LANKESTER, J. D.; Central England temperature quintiles and associated pressure anomalies on a monthly time-scale. *Met Mag, London*, **103**, 1974, pp. 3–14.

NICHOLASS, C. A., *see* HARROLD, T. W., ENGLISH, E. J. and NICHOLASS, C. A.

NICHOLLS, J. M., B.Sc.; The airflow over mountains. Research 1958–1972. *Tech Notes, Wld Met Org, Geneva*, No. 127, 1973.

PAINTING, D. J., *see* DAY, G. J., PAINTING, D. J. and SANDS, K. J. T.

PARDOE, C. W., *see* BROWNING, K. A., HILL, F. F. and PARDOE, C. W.

PARKER, D. E., B.Sc.; The synoptic-scale subprogram (for GATE). *Bull Amer Met Soc, Lancaster, Pa*, **55**, 1974, pp. 720–724.

PARKER, D. E., B.Sc. and HOUGHTON, D. D.; The synoptic-scale sub-programme for the GARP Atlantic Tropical Experiment. Rome, International Council of Scientific Unions, and Geneva, World Meteorological Organization. GATE Report No. 6, Geneva, 1974.

PARKER, D. E., B.Sc. and KANESHIGE, T. M.; GARP Atlantic Tropical Experiment (GATE). International Operations Plan. Part IV. Satellite operations plan. Rome, International Council of Scientific Unions, and Geneva, World Meteorological Organization. GATE Report No. 9, Geneva, 1974.

PASQUILL, F., D.Sc. and SMITH, F. B., Ph.D.; Eddy coefficients for vertical diffusion in the neutral surface layer. Comment on a paper by DEARDORFF, J. W. (*Boundary Layer Met, Dordrecht*, **5**, 1973, pp. 451–457). *Boundary Layer Met, Dordrecht*, **7**, 1974, pp. 227–228.

PETTIFER, R. E. W., B.Sc. and HEALEY, P. G.; Signal induced noise in a 56 TUVP photomultiplier. *J Phys, E, J Scient Instrum, London, Ser* 2, **7**, 1974, pp. 617–620.

PORTER, M. R., *see* BROWNSCOMBE, J. L., PORTER, M. R. and GOLDSMITH, P.

RATCLIFFE, R. A. S., M.A.; The use of 500 mb anomalies in long-range forecasting. *Q J R Met Soc, London*, **100**, 1974, pp. 234–244.

READINGS, C. J., Ph.D., D.I.C., *in* RAYMENT, R. and READINGS, C. J.; A case study of the structure and energetics of an inversion. *Q J R Met Soc, London*, **100**, 1974, pp. 221–233.

READINGS, C. J., Ph.D., D.I.C. and CAUGHEY, S. J., *in* GARLAND, J. A. *et alii*; Deposition of gaseous sulphur dioxide to the ground. *Atmos Environ, Oxford*, **8**, 1974, pp. 75–79.

READINGS, C. J., Ph.D., D.I.C. and BUTLER, H. E., *in* HAUGEN, D. A., PELLEGRINI, J., READINGS, C. J. and BUTLER, H. E.; Comparison of balloon-borne and tower-mounted turbulent wind and temperature sensors. *Proc 7th AFCRL Scient Balloon Symp, AFCRL Spec Rep, Bedford, Mass*, No. 152, 1973, pp. 93–101.

RICHARDS, C. J., *see* SALTER, PAULINE, M. and RICHARDS, C. J.

ROACH, W. T., Ph.D., D.I.C., ADAMS, R. J., M.Sc., GARLAND, J. A. and GOLDSMITH, P., M.A.; A field study of radiation fog. Faraday Symposium of the Chemical Society, London, No. 7, 1973, pp. 209–221.

ROY, MARJORIE, G., B.Sc.; Heading dates of S24 perennial ryegrass and spring temperatures. *J Br Grassld Soc, Aberystwyth*, **27**, 1972, pp. 251–260.

SALTER, PAULINE, M., B.Sc. and RICHARDS, C. J., B.Sc.; A memorable rainfall event over southern England. *Met Mag, London*, **103**, 1974, pp. 255–268 and 288–300.

SANDERSON, R. M.; The unusual waves off south-east Africa. *Mar Obsr, London*, **44**, 1974, pp. 180–183.

SANDS, K. J. T.; The meteorological offshore buoy observing equipment experiment, 1972. *Met Mag, London*, **103**, 1974, pp. 150–156.

SANDS, K. J. T., *see* DAY, G. J., PAINTING, D. J. and SANDS, K. J. T.

SANDS, K. J. T., *see* DAY, G. J., SANDS, K. J. T. and TONKINSON, B.

SANDS, K. J. T. and WILKINSON, D. G.; The meteorological transmission system operating between Beaufort Park and Meteorological Office Headquarters. *Met Mag, London*, **103**, 1974, pp. 74–81.

SAWYER, J., M.A., F.R.S.; Geomagnetism and the tropospheric circulation. Comment on a paper 'Weather and the earth's magnetic field' by KING, J. W. (*Nature, London*, **247**, 1974, pp. 131–134). *Nature, London*, **252**, 1974, pp. 368–370.

SAWYER, J. S., M.A., F.R.S.; Research in the atmospheric sciences—where next? *Bull Wld Met Org, Geneva*, **23**, 1974, pp. 9–13.

SAWYER, J. S., M.A., F.R.S.; The scientific objectives of the GARP Atlantic Tropical Experiment, *in* DANIEL, H.; The Atlantic Tropical Experiment—GATE (GARP Atlantic Tropical Experiment). Geneva, WMO, 1974, pp. 32–35.

SAWYER, J. S., M.A., F.R.S.; Weather forecasting—its past and future. *Tech Notes, Wld Met Org, Geneva*, No. 130, 1973, pp. 13–28.

SIMMONS, E. L., *see* FOOT, J. S., SIMMONS, E. L. and WHITTAKER, A. E.

SMITH, C. V., M.A., B.Sc.; Farm buildings. Heat loss from animals and man—assessment and control. Proceedings of the Twentieth Easter School in Agricultural Science, University of Nottingham, 1973, London, 1974, pp. 345–365.

SMITH, C. V., M.A., B.Sc.; Weather and the grain harvest. *Annls Tech Agric, Paris*, **22**, 1973, pp. 223–229.

SMITH, F. B., *see* CARSON, D. J. and SMITH, F. B.

SMITH, F. B., *see* PASQUILL, F. and SMITH, F. B.

SMITH, L. P., B.A.; The effect of temperature on the quality of hops. Unesco, Proceedings of the Uppsala Symposium on plant response to climate factors. (Ecology and conservation, 5), 1970, Paris, 1973, pp. 99–106.

SMITH, L. P., B.A.; Meteorological factors of importance in biological systems. TAYLOR, ANGELA E. R. and MULLER, R. (editors); The effects of meteorological factors upon parasites. *Symp Brit Soc Parasitol, Oxford,* **12,** 1974, pp. 1–12.

SMITH, L. P., B.A.; Weather lore. Encyclopædia Britannica, 15th edition. Chicago, Encyclopædia Britannica Inc., 1974, Macropædia Vol. 19, pp. 705–707.

SMITH, L. P., B.A. and OLLERENSHAW, C. B.; Animal husbandry. The role of weather in animal disease problems. *Vet Ann, Bristol,* No. 10, 1969, pp. 286–296.

SMITH, L. P., B.A.; *in* ALLEN, W. M., HERBERT, C. N. and SMITH, L. P.; Deaths during and after transportation of pigs in Great Britain. *Vet Rec, London,* **94,** 1974, pp. 212–214.

SMITH, L. P., B.A. *in* DAVIES, R. R. and SMITH, L. P.; Weather and the grass pollen content of the air. *Clin Allergy, Oxford,* **4,** 1973, pp. 95–108.

SMITH, M. F.; A short note on a sea-breeze crossing East Anglia. *Met Mag, London,* **103,** 1974, pp. 115–118.

SPALDING, T. R.; Satellite data for tropical weather forecasting. University of Bristol, Department of Geography. Environmental remote sensing: application and achievements. Paper presented at the Bristol symposium on remote sensing, Dept of Geography, University of Bristol, 2 October 1972, London, 1974, pp. 215–239.

STARR, J. R., Ph.D., D.I.C. and KEMP, B.; Mesoscale structure of jet streams and associated clear-air turbulence. *Met Mag, London,* **103,** 1974, pp. 313–329.

STEVENS, L. P.; An investigation into consecutive wet working days at Southampton. *Met Mag, London,* **103,** 1974, pp. 369–372.

STUBBS, M. W., B.Sc., *in* RICHARDS, P. and STUBBS, M. W.; An intense April depression. *Weather, London,* **29,** 1974, pp. 426–430.

TONKINSON, B. *see* DAY, G. J., SANDS, K. J. T. and TONKINSON, B.

WALES-SMITH, B. G.; Estimates and measurements of potential evaporation and evapotranspiration for operational hydrology. *Brit Rainf* 1967, *London,* 1973, Pt III, pp. 203–211.

WHITTAKER, A. E., *see* FOOT, J. S., SIMMONS, E. L. and WHITTAKER, A. E.

WHYTE, K. W.; The tornadoes of 26 June 1973. *Met Mag, London,* **103,** 1974, pp. 160–171.

WICKHAM, P. G., M.A.; Some examples of the rainfall forecasts produced by the fine-mesh version of the 10-level model. *Met Mag, London,* **103,** 1974, pp. 209–224.

WILKINSON, D. G., *see* SANDS, K. J. T. and WILKINSON, D. G.

YOUNG, J. A.; Rapid pressure rise followed by an oscillation of pressure during the passage of a trough at Liverpool Airport on 5 December 1972. *Met Mag, London,* **103,** 1974, pp. 171–177.

APPENDIX II

A SELECTION OF THE LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF

ADAMS, R. J., M.Sc. and GILES, W. G.

The weather service. *National Diploma of Horticulture Course, Kew Gardens, Richmond, Surrey.* 10 and 17 January.

AXFORD, D. N., Ph.D., A.I.E.E.

The Mk 3 radiosonde system. *Discussion Meeting, Royal Meteorological Society, London.* 20 November.

BEST, K. E.

Weather and sailing. *Royal Meteorological Society Course, Cowes, Isle of Wight.* 4–11 May.

BLACKHAM, A.

The weather routeing of ships. *Royal Institute of Navigation, Solent Branch, at the Southampton School of Navigation, Warsash.* 14 November.

BLACKWELL, M. J., M.A.

Some recent developments in instrumentation for the remote acquisition of meteorological data. *Royal Meteorological Society, Cardiff.* 30 October.

BROWNING, K. A., Ph.D., D.I.C.

Research at the Meteorological Office Research Unit, Malvern. *Appleton Laboratory, Slough.* 9 April.

Mesoscale structure of rain systems in the British Isles. *Atmospheric physics seminar, Clarendon Laboratory, Oxford.* 9 May.

BURRIDGE, D. M., Ph.D.

A split semi-implicit reformulation of the Bushby–Timpson 10-level model. *Exeter University, Mathematics Department.* 29 November.

CLARKE, MARY, FOORD, H. V., OGDEN, R. J., B.Sc. and SCOTT, J.

Recorded contributions to Radio London programme about meteorology as a career. 5 August.

COLLIER, C. G., B.Sc.

The accuracy of radar measurements of rainfall. *Symposium on Weather Radar for Quantitative Rainfall Measurement and Development in Data Remoting. Institution of Electrical Engineers, London.* 25 November.

COLLINGBOURNE, R. H., M.Sc., D.I.C.

Radiation measurement. *Royal Meteorological Society One-day Discussion Meeting. University College, London.* 26 October.

CORBY, G. A., B.Sc.

The role of the FGGE for analysis and weather forecasting in middle latitudes. *WMO CBS–VI, Belgrade.* 3 April.

CRADDOCK, J. M., M.A.

A computer language for ordinary meteorologists. *Hungarian Meteorological Service, Budapest.* 3 September.

Keeping track of meteorological information (a) by manual methods, (b) by computer. *Hungarian Meteorological Service, Budapest.* 3 September.

Scientific techniques rendered practicable by (a) a bank of high grade data readable by computer and (b) a fluent and versatile computer language. *Hungarian Meteorological Service, Budapest.* 4 September.

Computer methods in climatology. *University of East Anglia, Norwich.* 17 September.

CULLEN, M. J. P., M.A.

Finite element methods in meteorological problems. *Exeter University.* 21 February.
National Center for Atmospheric Research, Boulder, Colorado. 27 September.
Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey. 30 September.

Fourier analysis and the finite element method. *Reading University.* 18 March.

Application of the finite element method to meteorological problems. *Atlas Computer Laboratory, Culham.* 26 March.

Solution of weather prediction problems by finite element methods. *Texas Institute of Computational Mechanics, University of Texas, Austin.* 23 September.

DALTON, F.
Understanding the weather. *Course of* 12 *lectures to the Workers' Educational Association, High Wycombe, Bucks.* 24 September–10 December.

DAVIES, T. M., B.Sc.
Weather forecasting. *Sixth Form lecture, Mathematical Association, Westminster School.* 16 October.

DAY, G. J., B.Sc. and PAINTING, D. J.
Automatic weather stations, systems and sensors. *Discussion Meeting, Royal Meteorological Society, London.* 20 November.

DEEKS, P. H. G.
Weather and bees. *Essex Beekeepers' Society, Field Study Centre, Loughton, Essex.* 22 April.
Weather and watersports. *Borough of Barking Youth Activities Officers.* 30 May.
Weather and diving. *British Sub-aqua Association Conference, London.* 17 November.
Weather forecasting and the yachtsman. *East Anglian Section of the Cruising Association, Ipswich.* 22 November.
Weather records. *Cement and Concrete Association, Slough.* 12 December.

DOUGLAS, H. A., B.Sc.
Visibility devices. *Discussion Meeting, Royal Meteorological Society, London.* 20 November.

FISH, M. J.
Aspects of Public Service Forecasting. *Popular/Sixth Form lecture, Royal Meteorological Society, London.* 5 and 6 December.

FOLLAND, C. K., B.Sc., Grad. Inst .P.
Humidity devices. *Discussion meeting on recent developments in operational instrumentation. Royal Meteorological Society, London.* 20 November.

FOOT, J. S., Ph.D.
An acoustic method for measuring the absorption of solar radiation. *Joint COMESA/COVOS symposium on the meteorological effects of stratospheric aircraft, Oxford.* 26 September.

GADD, A. J., Ph.D.
Recent developments in numerical weather prediction. *Department of Oceanography, Southampton University.* 15 November.

GOLDSMITH, P., M.A.
The SST pollution question. *Pollution research colloquium of the Inter-Research Council Committee on Pollution, Royal Society, London.* 20 May.
Inadvertent weather modification. *Department of Meteorology, Reading University.* 29 May.
Advertent weather modification. *Department of Meteorology, Reading University.* 28 June.
Chemical weather modifications. *Physical Chemical Laboratory, Oxford.* 21 October.
SST pollution. *Royal Radar Establishment, Malvern.* 28 November.

GOODISON, C. E., C.Eng., M.I.E.R.E.
Meteorological telecommunications systems engineering. *Institution of Electronic and Radio Engineers, District meeting, Farnborough.* 31 January.

GRAYSTONE, P., B.A.
Environmental effects of supersonic aircraft. *Royal Meteorological Society, Scottish Branch, Edinburgh.* 25 January.
The use of computers in weather forecasting. *British Computer Society, Croydon Branch.* 22 October.

HARPER, W. G., M.Sc.
Meteorology in agriculture. *Agrarian Society of Glasgow.* 25 November.

HARROLD, T. W., Ph.D., D.I.C.
The measurement of area rainfall using a radar system. *Conference of River Engineers, Cranfield.* 26 September.
The use of weather radar in short term meteorological forecasting. *Symposium on Weather Radar for Quantitative Rainfall Measurement and Development in Data Remoting. Institution of Electrical Engineers, London.* 25 November.

HIDE, R., Sc.D., F.R.S.
Motions in planetary atmospheres.
Oxford University. 15 March.
Atomic Energy Research Establishment, Culham Laboratory. 27 March.
Mathematics Department, University of East Anglia. 29 April.

Core-mantle coupling.
Royal Astronomical Society, London. 10 April.
International symposium on mathematical geophysics. Cambridge University. 26 June.
Rotating fluids. *Department of Physics, University of Southampton.* 14 October.
A note on helicity. *Department of Mathematics, University College, London.* 1 November.
Jupiter's rotation and atmospheric dynamics. *Joint Royal Meteorological Society/Royal Astronomical Society meeting, London.* 8 November.
Jupiter's magnetism. *V.C.A. Ferraro Memorial Symposium, Queen Mary College, London.* 15 November.

HOOPER, A. H.
Performance of the Mark 3 radiosonde. *Discussion Meeting. Royal Meteorological Society, London.* 20 November.

HOUGHTON, D. M., M.Sc., D.I.C.
Forecasting snow. *Royal Meteorological Society One-day Meeting, London.* 6 January.
The spectrum of the winds. *Conference of National Schools Sailing Association, Lytham St Annes.* 19 January.
Wind forecasting for Olympic yachting. *Staff College, Sandhurst.* 5 February.
Patterns in the wind, offshore. *Royal Ocean Racing Club, London.* 14 February.
Patterns in the wind, inshore. *Royal Ocean Racing Club, London.* 28 February.
Winds over Lake Ontario. *Grafham Water Sailing Club, Henlow, Beds.* 22 November.

HUGHES, I. G.
Meteorology for nuclear fallout prediction and Civil Defence. *Home Office Defence College, Easingwold, Yorks.* 9 October.

HUNT, G. E., Ph.D., F.I.M.A.
First results of PIONEER 10 mission to Jupiter. *British Astronomical Association, London.* 2 January.
Jupiter. *A contribution to BBC World Service radio programme 'Discovery'.* 5 February.
Saturn. *BBC-TV 'Sky at Night'.* 16 February.
Space exploration of Jupiter and Saturn. *Maxwell Society, King's College, London.* 17 February.
Spectroscopic evidence for variations in the structure of the visible Jovian clouds. *Division of Planetary Sciences, American Astronomical Society, Palo Alto, California.* 3 April.
Mercury—the winged messenger. *BBC-TV 'Sky at Night'.* 24 April.
Mercury—first results from MARINER 10. *British Astronomical Society, London.* 24 April.
The atmosphere of Jupiter. *European Geophysical Society, Trieste.* 26 September.
Weather and climate of planetary atmospheres. *West Midlands Branch of the Institute of Physics, University of Birmingham.* 8 October.
The meteorological significance of Jupiter's visible appearance. *Joint meeting of the Royal Astronomical Society and the Royal Meteorological Society, London.* 8 November.
PIONEER 11 and Jupiter. *BBC-TV 'Sky at Night'.* 14 December.

JACKSON, M. C., M.Sc.
Weather science and forecasting. *Royal Meteorological Society course, Nettlecombe Court, Williton, Somerset.* 7–14 August.

JAMES, D. G., Ph.D.
Contributions to several radio and television programmes, with other members of the Meteorological Research Flight, on the new Hercules aircraft and GATE.

JOHNSON, G. C.
Meteorology and mountaineering. *Course of 4 lectures at Mountain Expedition Training Centre, Brent, Middx.* 13 February–24 April.

JONAS, P. R., Ph.D.
The 10-level model of the atmosphere. *Institute of Mathematics and its Applications, East Midlands Branch.* 5 December.

JONES, D. E., B.Sc.
The Meteorological Office fine-mesh model.
Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey. 11 July.
National Center for Atmospheric Research, Boulder, Colorado. 15 July.

JONES, M. V., B.Sc.
The use of computers in weather forecasting. *British Computer Society, Chester and North Wales Branch, Colwyn Bay.* 4 April.

JONES, R. F., B.A.
Contribution on GATE to BBC World Service radio programme 'Science in Action'. 19 June.

KEERS, J. F., B.Sc.
Meteorological aspects of drainage design. *Planning and Transport Research and Computation Co. Ltd Course on Drainage Design, London.* 11 November.

KIRK, T. H., B.Sc.
Forecast evaluation—its scope and future. *American Meteorological Society, Fifth Conference on Weather Forecasting and Analysis, St Louis, Missouri.* 4–7 March.
The use of numerical forecasts in the Central Forecasting Office, Bracknell. *Royal Meteorological Society Summer Meeting. Exeter University.* 1–2 August.

McILVEEN, W. A., Ph.D.
Mathematics and computing in weather forecasting. *Mathematics Conference for First-year Sixth Formers, School of Mathematics, University of Bath.* 16–18 July.

MACKIE, G. V.
The weather routeing of ships. *Royal Institute of Navigation, Humber Branch, Hull.* 28 November.

MASON, B. J., C.B., D.Sc., F.R.S.
The work of the Meteorological Office. *Rumford Club, London.* 21 February.
The role of satellites in sensing the global atmosphere and their application to weather forecasting. *Remote Sensing Society, University College, London.* 28 February.
The future of weather forecasting. *Royal Geographical Society, London.* 4 March.
Weather forecasting in the satellite and computer age.
Fourth Thames Polytechnic Lecture, London. 19 March.
Celebrity Lecture, British Association Science Fair, University College, London. 4 July.
Physics applied to weather forecasting. *Institute of Physics, Plymouth Polytechnic.* 28 March.
The numerical modelling of cumulus clouds and the initiation of showers.
Institute of Geophysics, University of Bergen. 3 May.
Atmospheric Physics Seminar, University of Oxford. 23 May.
Numerical modelling of weather and climate. *50th anniversary celebrations of the opening of the laboratories of the Department of Pure Science, University of Durham.* 21 November.

MATHESON, J. C.
The work of the Marine Branch in general and the Port Meteorological Officers in particular. *Meteorological Office College, Shinfield Park, Reading.* 14 October.

MATTINGLY, S. R., Ph.D.
A 13-level general circulation model of the troposphere and stratosphere. *Heriot-Watt University, Edinburgh.* 4 November.

MENMUIR, P., B.Sc.
The automated production of weather maps. *Joint Meeting of British Cartographic Society and Geographical Association, Taunton.* 17 October.

MILES, M. K., M.Sc.
Contribution to BBC-TV 'The Weather Machine'. 23 November.

NICHOLLS, J. M., B.Sc.
Contribution to Voice of America radio broadcasts on GATE. 1 and 23 September.

OGDEN, R. J., B.Sc.
The environment for off-shore engineering. *Department of Civil and Structural Engineering, University College, Cardiff.* 18 January.
Weather forecasting and the community. *Balls Park Teachers' Training College, Hertford.* 5 February.
Weather forecasting and some applications to engineering. *Women's Engineering Society, City University, London.* 5 March.
Weather forecasting and future trends. *B.Sc. (Hons) Geography course, Middlesex Polytechnic, Hendon.* 2 May.
Weather forecasting and some applications to aviation. *M.Sc. Aerodynamics seminar. College of Aeronautics, Cranfield, Beds.* 3 May.
Recorded contribution to BBC-TV programme on North Sea Technology. 28 May.
Live question and answer broadcast on BBC Radio 4 programme on meteorology, with R.A.S. Ratcliffe. 6 September.
Recorded contributions to BBC Radio 3 programme on meteorology. 8 October.
Weather forecasting and some applications to the railways. *British Rail Permanent Way Institution, Ashford, Kent.* 15 October.
Weather forecasting—physics in action. *Cambridge University Physics Society.* 24 October.
Weather forecasting in relation to forest fire hazards. *Forestry Commission Conference, Pitlochry.* 5 November.

PETTIFER, R. E. W., B.Sc.

Short term enhanced dark current in photomultipliers and its relevance to the interpretation of laser experiments. *Joint COMESA/COVOS symposium on the meteorological effects of stratospheric aircraft, Oxford.* 26 September.

The use of lasers for measurements of the high atmosphere. *Physical Society of Reading.* 5 December.

PHILPOTT, L. B., D.S.C., R.D.

The work of the Marine Branch in general and the Port Meteorological Officers in particular. *Meteorological Office College, Shinfield Park, Reading.* 9 May and 17 June.

PLUMB, R. A., Ph. D.

Some aspects of finite amptitude baroclinic waves in the laboratory. *University College, London.* 31 May.

RATCLIFFE, R. A. S., M.A.

Live question and answer broadcast on BBC Radio 4 programme on meteorology, with R. J. Ogden. 6 September.

Contribution to BBC Radio 3 'Context Study on 3'. 10 October.

Contribution to BBC-TV 'The Weather Machine'. 23 November.

READINGS, C. J., Ph.D., D.I.C.

Mixing in the atmosphere—review from the viewpoint of an atmospheric scientist. *Euromech colloquium, Department of Applied Mathematics and Theoretical Physics. Cambridge University.* 25 June.

RIGDEN, H. L.

Weather and sailing. *Course of 10 lectures covering RYA/DTI Yachtmaster Off-shore Certificate. Poole Technical College, Dorset.* 16 September–18 November.

ROACH, W. T., Ph.D., M.Sc., D.I.C.

Interview on 'Late News' for BBC-TV concerning the possible causes of the tomato disaster which swept the Eastern Plains States of the United States of America. 2 April.

The physics of radiation fog. *Scottish Branch of the Royal Meteorological Society, Edinburgh.* 8 November.

RYDER, P., Ph.D.

Navaid windfinding techniques, GATE experience. *Discussion Meeting, Royal Meteorological Society, London.* 20 November.

SANDS, K. J. T.

Buoys, moored and drifting. *Discussion Meeting, Royal Meteorological Society, London.* 20 November.

SAWYER, J. S., M.A., F.R.S.

Can man's waste heat affect the regional climate? *First Special Assembly of the IAMAP, Melbourne.* 18 January.

A contribution to BBC Radio 3 programme 'Scientifically Speaking' on climatic change. 8 April.

A contribution to BBC World Service programme on 'International Weather'. 22 and 27 September.

SIMMONS, E. L., M.A., Ph.D.

World wide total ozone measurements. *Joint COMESA/COVOS symposium on the meteorological effects of stratospheric aircraft, Oxford.* 26 September.

SINGLETON, F., B.Sc., D.I.C.

Weather and sailing.

Queen Mary Sailing Club, near Staines, Middx. 11 January and 15 March.

ICI Sailing Club, Slough. 27 February.

Royal Meteorological Society Course, Cowes, Isle of Wight. 4–11 May.

SMITH, C. V., M.A., B.Sc.

Simulation of onion bulb temperatures and implications for keeping quality. *ADAS Regional Conference, Cambridge.* 13 November.

SMITH, D. P.

Elementary meteorology. *Course of 26 lectures given to the London Borough of Hounslow (Adult Education Service).* 11 January–5 April, and 20 September–13 December.

Ship icing, especially off Iceland. *Fishing Skippers' Course, Grimsby College of Technology.* 11 June.

SMITH, F. B., Ph.D.

Prediction of dispersion in the atmosphere. *Imperial College of Science and Technology, London.* 27 March.

Meteorological aspects of air pollution. *Chemical Society joint symposium, Aston University.* 15 May.

Modelling of long-range transport. *Central Electricity Research Laboratories, Advisory Panel on Environmental Research meeting, Reading.* 11 July.

Meteorology and air pollution. *Course in pollution for the diploma of health, Leeds Polytechnic.* 26 September.

SMITH, L. P., B.A.

Weather and disease. *Seminar at Nuffield Institute of Comparative Medicine, London.* 11 November.

SPALDING, T. R.

Mountain weather. *Course of lectures to the Royal Meteorological Society Field Studies Course, Betws-y-coed.* 31 July–7 August.

STARR, J. R., Ph.D., D.I.C.

Use of radar in meteorology. *Institution of Electrical Engineers, South Worcestershire Branch, Malvern.* 14 January.

Clouds, rain and rainmaking.

Physical Society, Durham University. 4 March.

Physical Society, York University. 3 December.

Radar studies of small-scale atmospheric instabilities. *Department of Applied Mathematics and Theoretical Physics, Cambridge University.* 15 March.

Physics of rain, snow and hail. *Physical Society, Nottingham University.* 17 October.

STEVENS, L. P.

Weather forecasting. *British Association of Young Scientists, Cowes, Isle of Wight.* 19 March.

STEWART, J. B., B.Sc., D.I.C.

The Thetford Project. *International Union of Forestry Research Organizations' Symposium on Processes in Forest Canopies, Brandon, Suffolk.* 19 September.

TEMPERTON, C., B.Sc.

Dynamic intialization: some new theoretical and experimental results. *European Geophysical Society, Trieste.* 26 September.

THOMAS, E. R., B.Sc.

Operational use of weather. *Royal Military College of Science, Shrivenham.* 11 July.

THOMPSON, N., Ph.D.

Convection over the sea. *Interaction symposium, IAMAP/IAPSO combined First Special Assembly, Melbourne.* 22 January.

Features of atmospheric turbulence over the sea. *Department of Oceanography, University of Southampton.* 6 June.

WALES-SMITH, B. G.

Intensity-duration-frequency analysis of rainfall data for storm drainage design: a survey.

Institute of British Geographers, Applied Environmental Sciences Seminar, University of East Anglia. 6 January.

Planning and Transport Research and Computation Co. Ltd Course on Highway Drainage Design, London. 20 May.

The relevance of a proposed British Soil Moisture Network to the production of soil moisture deficit maps. *Anglo-Nordic meeting on soil water in catchment hydrology, Institute of Hydrology, Wallingford.* 24 October.

WHITE, G. D.

Weather study. *Course of lectures to the Workers' Educational Association, Holyhead.* January and February.

WHITE, P. W., Ph.D.

Boundary layer modelling at the British Meteorological Office. *National Center for Atmospheric Research, Boulder, Colorado.* 7 November.

WICKHAM, P. G., M.A.

Low-level meteorology. *Airship Association, London.* 3 October.

YOUNG, E. E.

Weather and sailing. *Lymington Sailing Club, Lymington, Hants.* 6 April.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. Catalogues listing all the publications which may be purchased through the sales offices or usual agents of Her Majesty's Stationery Office, or direct from the Meteorological Office at Bracknell, are sent free to any applicant.

The following publications have been issued:

PERIODICAL

Annual Report on the Meteorological Office 1973.

Daily Aeronautical Record containing information in respect of meteorological conditions in the upper air for the British Isles.

Daily Weather Report containing weather maps for the northern hemisphere, British Isles, etc., and data.

Daily Weather Report, Overseas Supplement containing surface and upper-air data (to 31 December 1971).

Monthly Summary of the *Daily Weather Report.*

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for the United Kingdom, the weather of the past month, a general survey and inference, and weather prospects for the coming month in the United Kingdom; a supplementary document, containing survey, inference and prospects only, is published in mid month.

Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain, a seasonal fortnightly publication providing estimates of soil moisture deficit in map form and as a tabular statement for river authority areas.

Sea Ice Charts (daily).

Monthly (coloured) *Ice Maps* (to September 1974).

Meteorological Magazine (monthly).

Monthly Weather Report (to February 1974).

Marine Observer (quarterly).

British Rainfall—annual volume for 1967.

Printed in England for Her Majesty's Stationery Office by McCorquodale Printers Ltd., London
HM 7343 Dd 289476 K9 8/75 McC3309

HER MAJESTY'S STATIONERY OFFICE

Government Bookshops

49 High Holborn, London WC1V 6HB
13a Castle Street, Edinburgh EH2 3AR
41 The Hayes, Cardiff CF1 1JW
Brazennose Street, Manchester M60 8AS
Southey House, Wine Street, Bristol BS1 2BQ
258 Broad Street, Birmingham B1 2HE
80 Chichester Street, Belfast BT1 4JY

Government publications are also available through booksellers

£1.80 net

ISBN 0 11 400288 6